

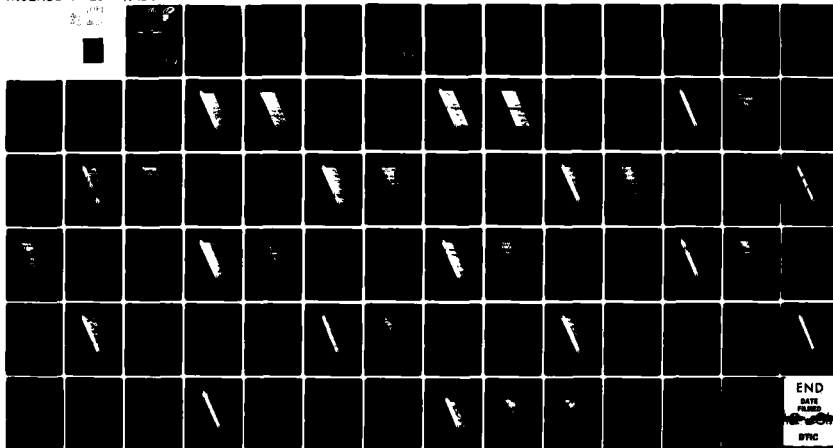
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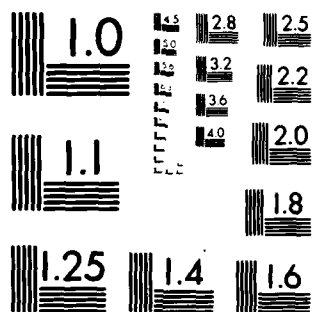
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VLF/LF REFLECTIVITY OF THE POLAR IONOSPHERE.(U)
JUN 80 R P PAGLIARULO, J P TURTLE
RADC-TR-80-189

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In-House Report

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**VLF/LF REFLECTIVITY OF
THE POLAR IONOSPHERE.**

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Rept. for 2 SEPTEMBER - 22 DECEMBER 1979.

Robert P. /Pagliarulo
John P. /Turtle
John E. /Rasmussen
Wayne I. /Klemetti

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**ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441**

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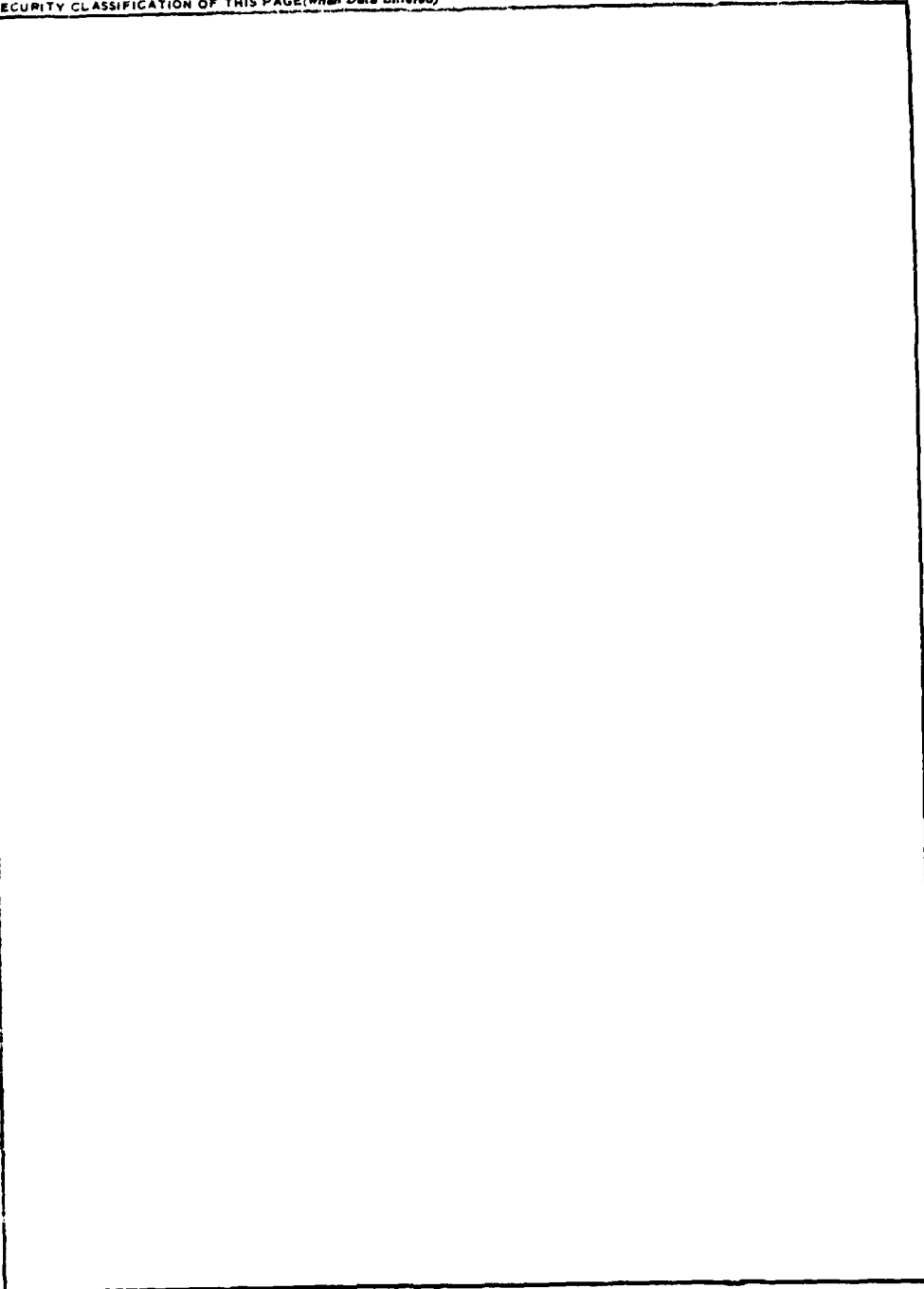
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Preface

The authors thank in particular Mr. Duane Marshall of Megapulse, Inc., for help with the equipment that made the measurements possible, and Mr. Bjarne Ebbesen of the Danish Meteorological Institute for the outstanding operation at Qanaq, Greenland.

Appreciation is also extended to the Danish Commission for Scientific Research in Greenland for allowing these measurements to be conducted, and to Jorgen Taagholt and V. Neble Jensen of the Danish Meteorological Institute's Ionospheric Laboratory for their continued cooperation in this program.

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VLF/LF Reflectivity of the Polar Ionosphere

2 September—22 December 1979

1. INTRODUCTION

This report provides a summary of high latitude ionospheric reflectivity data, as observed by the USAF's high resolution VLF/LF ionosounder operating in northern Greenland.^{1, 2} As shown in Figure 1, the transmitter is located at Thule Air Base Greenland (76°33'N. Lat., 68°40'W. Long.), and the receiving site is 106 km north at the Danish Meteorological Institute's Ionospheric Observatory in Qanaq, Greenland (77°24'N. Lat., 69°20'W. Long., Geomagnetic Lat. 89°06'N.). The ionosounding transmissions consist of a series of extremely short (approximately 100 μ sec) VLF pulses, precisely controlled in time, and radiated from a 130 m vertical antenna. At the receiving site, orthogonal loop antennas are used to separate the two polarization components of the ionospherically reflected sky-wave signal. One antenna, oriented in the plane of propagation, is used to sense the groundwave and the transmitted or "parallel" polarization component of the skywave. The second loop, nulled on the groundwave, senses the converted or "perpendicular" polarization skywave component. The signal from each of the

(Received for publication 17 June 1980)

1. Lewis, E.A., Rasmussen, J.E., and Kossey, P.A. (1973) Measurements of ionospheric reflectivity from 6 to 35 kHz, J. Geophys. Res. 78:19.
2. Kossey, P.A., Rasmussen, J.E., and Lewis, E.A. (1974) VLF pulse ionosounder measurements of the reflection properties of the lower ionosphere, Akademie Verlag, COSPAR, July.

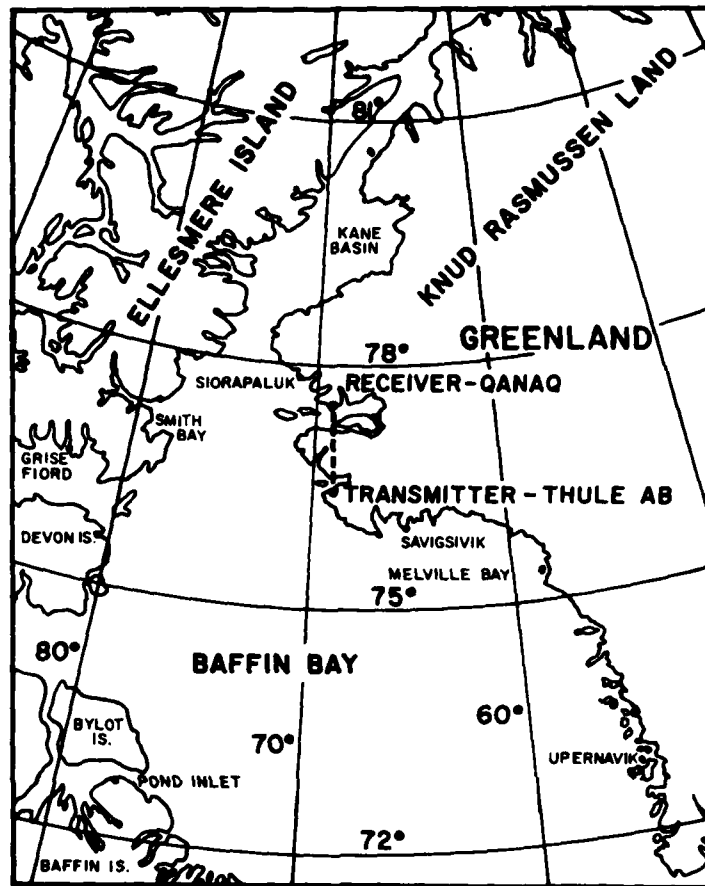


Figure 1. Geometry of the Propagation Path

antennas is digitally averaged to improve the signal-to-noise ratio of the individual received waveforms before they are recorded on magnetic tape. An example of the observed waveforms is given in Figure 2, where the "parallel" waveform (Figure 2a) consists of a groundwave propagated pulse, a quiet interval containing low level, off-path groundwave reflections, followed by the first-hop parallel skywave component. The perpendicular waveform is shown in Figure 2b. Each of these waveforms is comprised of 256 digitally averaged points spaced $2 \mu\text{sec}$ apart.

Ionospheric reflection parameters are derived by computer processing of the ground and ionospherically reflected waveforms with allowance made for factors such as ground conductivity and antenna patterns (see Section 4).

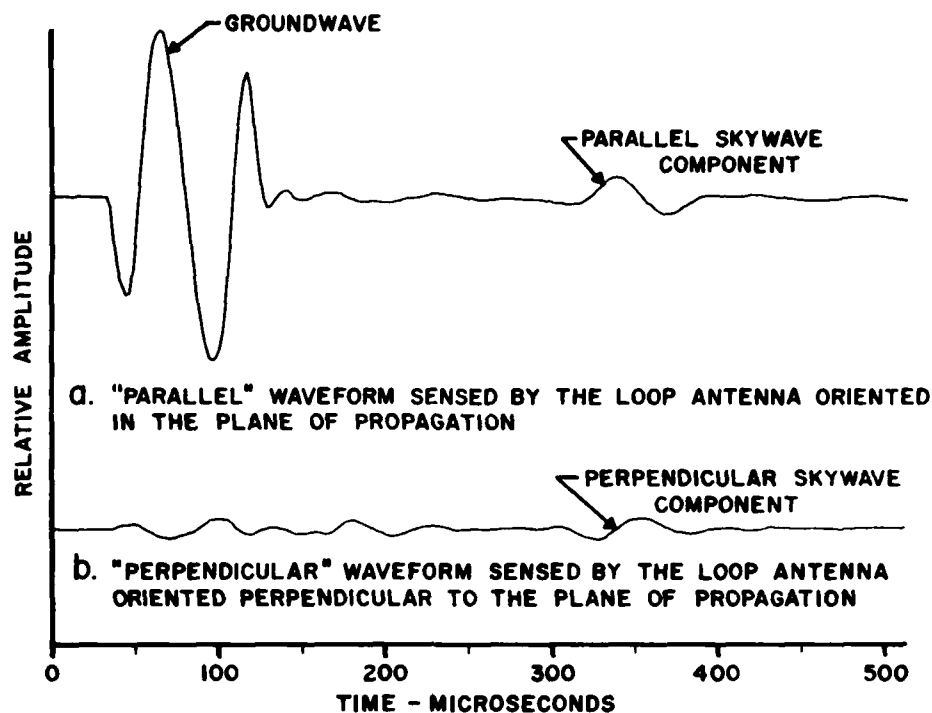


Figure 2. Example of the Observed Waveforms

Although the data are recorded about once per minute, for this report the waveforms are averaged into 2-hr time blocks with the exception of the three-dimensional waveform presentations (Section 2.2). The resulting information is presented in a weekly format (Figures 3 through 18 as described below).

2. OBSERVATION

2.1 Weekly Example of Individual Waveforms

In part A of Figures 3 through 18, a set of averaged parallel and perpendicular waveforms is presented for the time block centered near local noon of the indicated day. In part B of the figures, the groundwave Fourier amplitudes are shown as a function of frequency. Although the data presented in parts C through L of the figures are generally limited to frequencies in the first, or principal, lobe of the spectrum, information at higher frequencies can be used when sufficient signal-to-noise conditions exist. There is, however, a frequency range around each spectral null where insufficient signal exists for measurements.

2.2 Three-Dimensional Waveform Presentation

The three-dimensional display of the recorded parallel waveforms covering each weekly period is shown in part R of each figure, and the corresponding display of the perpendicular waveforms is shown in part S. For these plots the data has been averaged into 15-min time blocks.

3. REFLECTION HEIGHTS

The group mirror height (GMH) reflection was obtained by determining the group delay of the skywave relative to the groundwave and attributing the time difference, by simple geometry (assuming a sharply-bounded mirror-like ionosphere) to a difference in propagation distance. As discussed in Lewis et al,¹ the group delay can be defined as the rate of change of phase with frequency. For the GMH data presented in this report, a finite frequency difference of 1.0 kHz was used, and the corresponding phase difference as a function of frequency for the groundwave and both skywave signals was obtained by Fourier analysis of the respective pulses. The GMH calculations took into account ground conductivity (10^{-3} mho/m is assumed), and the corrections of Wait and Howe³ were applied. Group mirror heights, obtained from the parallel and perpendicular waveforms, are plotted as a function of frequency in parts C and D of Figures 3 through 18. The GMH's are also presented as a function of time-of-day for the average frequency of 16.5 kHz in figure parts E and I. The parallel GMH's in part E are shown along with an average reflection height for reference purposes. Each point of the reference height is a weekly average, by time block, for the 7-day period indicated. The corresponding perpendicular GMH's, part I of the figures, are also shown with the weekly average for comparison. Part G gives the average, by time block, for the daily parallel GMH data of part E, and part K gives the corresponding perpendicular GMH averages from the daily data of part I.

4. REFLECTION COEFFICIENTS

Assuming that the ionosphere acts as a "mirror" at the GMH, plane wave reflection coefficients⁴ were obtained by comparing the ratio of the skywave Fourier amplitude at a specific frequency to that of the groundwave, taking into

3. Wait, J.R., and Howe, H.H. (1956) Amplitude and Phase Curves for Ground-Wave Propagation in the Band 200 Cycles per Second to 500 Kilocycles, Nat. Bur. Stand. U.S. Circ. No. 574.
4. Budden, K.G. (1961) Radio Waves in the Ionosphere, p. 85, Cambridge University Press, London.

account the antenna patterns, wave spreading, earth curvature, ground conductivity, path lengths, and antenna patterns including ground image effects.

The reflection coefficient R_{\parallel} was obtained from analysis of the parallel sky-wave component and is plotted as a function of frequency in part C of Figures 3 through 18. The R_{\parallel} coefficient for 16 kHz is plotted as a function of time-of-day in part F along with the average of the indicated week for reference purposes. From the perpendicular skywave pulse, the coefficient R_{\perp} was obtained and appears as a function of frequency in part D. The 16 kHz R_{\perp} is shown along with its reference in part J. Parts H and L present the average, by time block, of the daily R_{\parallel} and R_{\perp} data presented in parts F and J, respectively.

For certain coefficient data points, plotted as asterisks (*), the reflection coefficient appears without a corresponding GMH. For these particular data, only the skywave-groundwave ratios could be obtained as the skywaves were too weak to provide reliable group delay information. The reflection coefficients were therefore estimated using a nominal GMH of 80 km in the calculations. These estimated coefficient values are included in the averages presented in parts H and L, but the assumed heights are not used in the GMH averages shown in parts G and K.

5. SUPPLEMENTARY INFORMATION

For purposes of comparison and interpretation, information on the condition of the polar propagation environment is presented. Part M of the figures shows the magnitude of the horizontal component of the polar magnetic field are recorded on a three-axis fluxgate magnetometer and part N presents 30-MHz riometer data, an indicator of D-region particle precipitation. These supplementary data were recorded at 20-sec intervals by RADC/EEP at Thule AB; the curves represent the average of 10-min periods. The solar zenith angle is given in part O of Figures 3 through 18 for the indicated mid-week date.

6. IONOSPHERIC DISTURBANCE DATA

Ionospheric disturbance activity continued during the period covered by this report. Although there were no outstanding events, the effects of several small PCA disturbances are seen in the data. The first of these was a long-lasting event which began on 8 September (DAY 251). The ionosounding reflection heights and coefficients indicate that disturbed conditions lasted continuously through 8 October (DAY 281). The effects on the daytime reflection coefficients were more persistent; the reflection heights had recovered by 1 October, while the daytime reflection coefficients did not return to normal until 8 October. The riometer data show

a maximum of 2 dB absorption on 17 September (DAY 260). The riometer recovered to normal levels on 23 September (DAY 266), and during the rest of the event, disturbance levels remained below the riometer detection threshold. The effects of additional small disturbances are seen in the ionosounding data on 9 November (DAY 313), 16 November (DAY 320) and 21 November (DAY 325). The 9 and 21 November events were below the riometer detection level, while the 16 November event produced 1.5 dB absorption.

During strong ionospheric disturbances, when enhanced ionization produces a lowering of the VLF/LF reflection heights, the skywave moves closer to the groundwave, as seen on the waveform plots. In particularly energetic events, the skywave can merge with the low-level off-path signal reflection (described in the Introduction). During these periods, the constant off-path groundwave reflections are computer-subtracted from the waveforms so as not to interfere with the skywave reflections. During the period covered by this report, this subtraction technique was used in the parallel and perpendicular waveform data for the week periods beginning on the following days: DAY 245 (Figure 3), DAY 252 (Figure 4), DAY 259 (Figure 5), DAY 266 (Figure 6), DAY 273 (Figure 7), DAY 315 (Figure 13), and DAY 322 (Figure 14).

7. ADDITIONAL COMMENTS

This report is one of a series.⁵⁻¹⁹ Comments and suggestions for improving its usefulness should be addressed to the Propagation Branch (EEP), Electromagnetic Sciences Division, Deputy for Electronic Technology (RADC/EEP), Hanscom AFB, Massachusetts 01731.

Due to the large number of references cited above, they will not be listed here. See References, page 77.

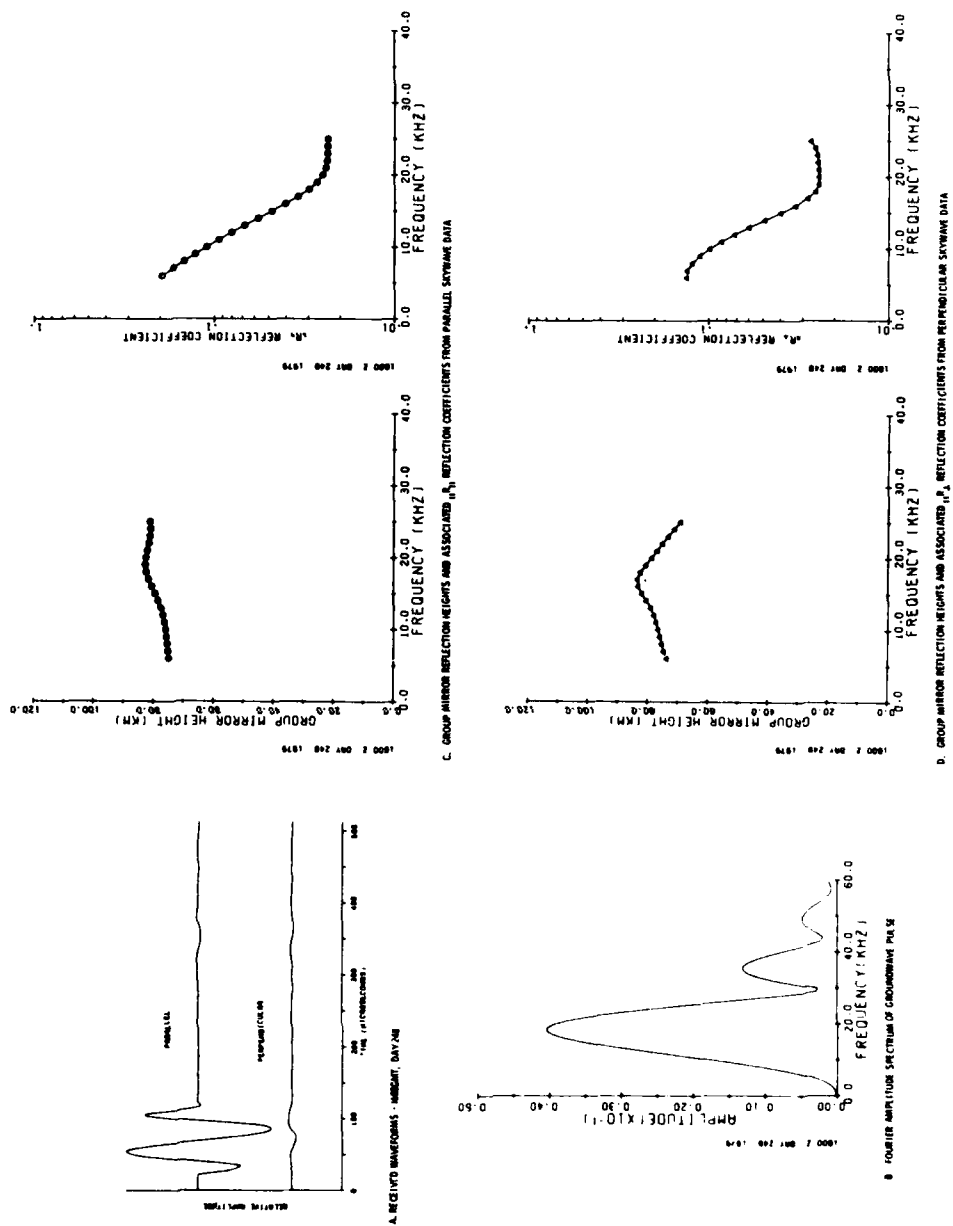
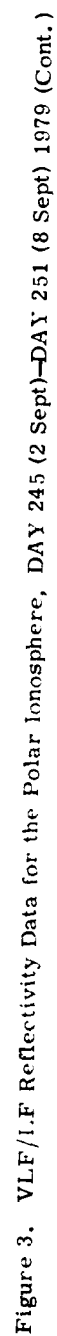
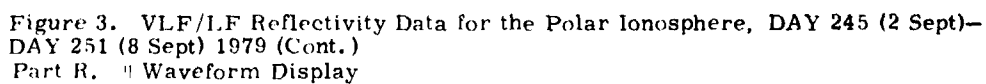


Figure 3. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 245 (2 Sept)–DAY 251 (8 Sept) 1979





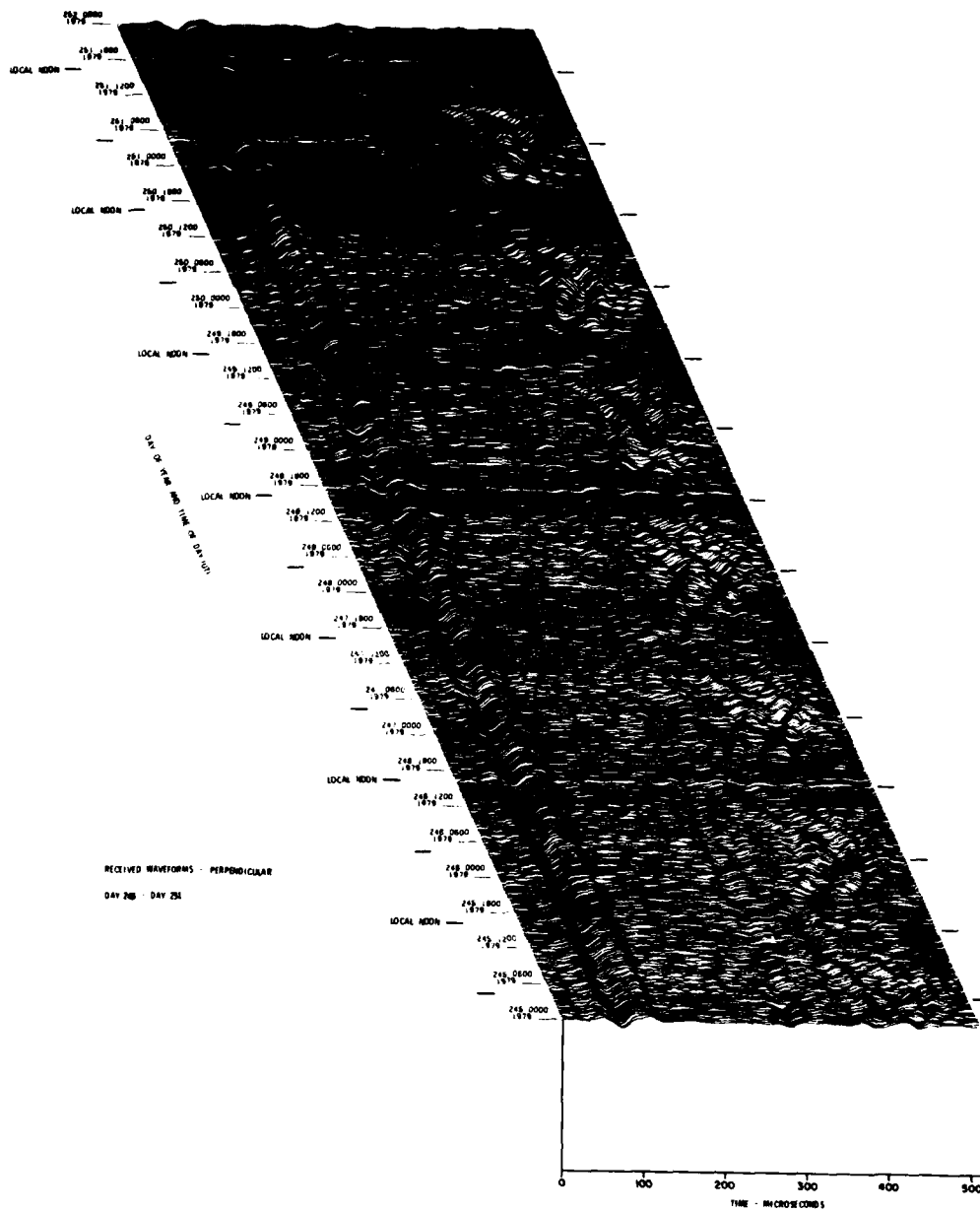


Figure 3. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 245 (2 Sept)-
DAY 251 (8 Sept) 1979 (Cont.)
Part S. 1 Waveform Display

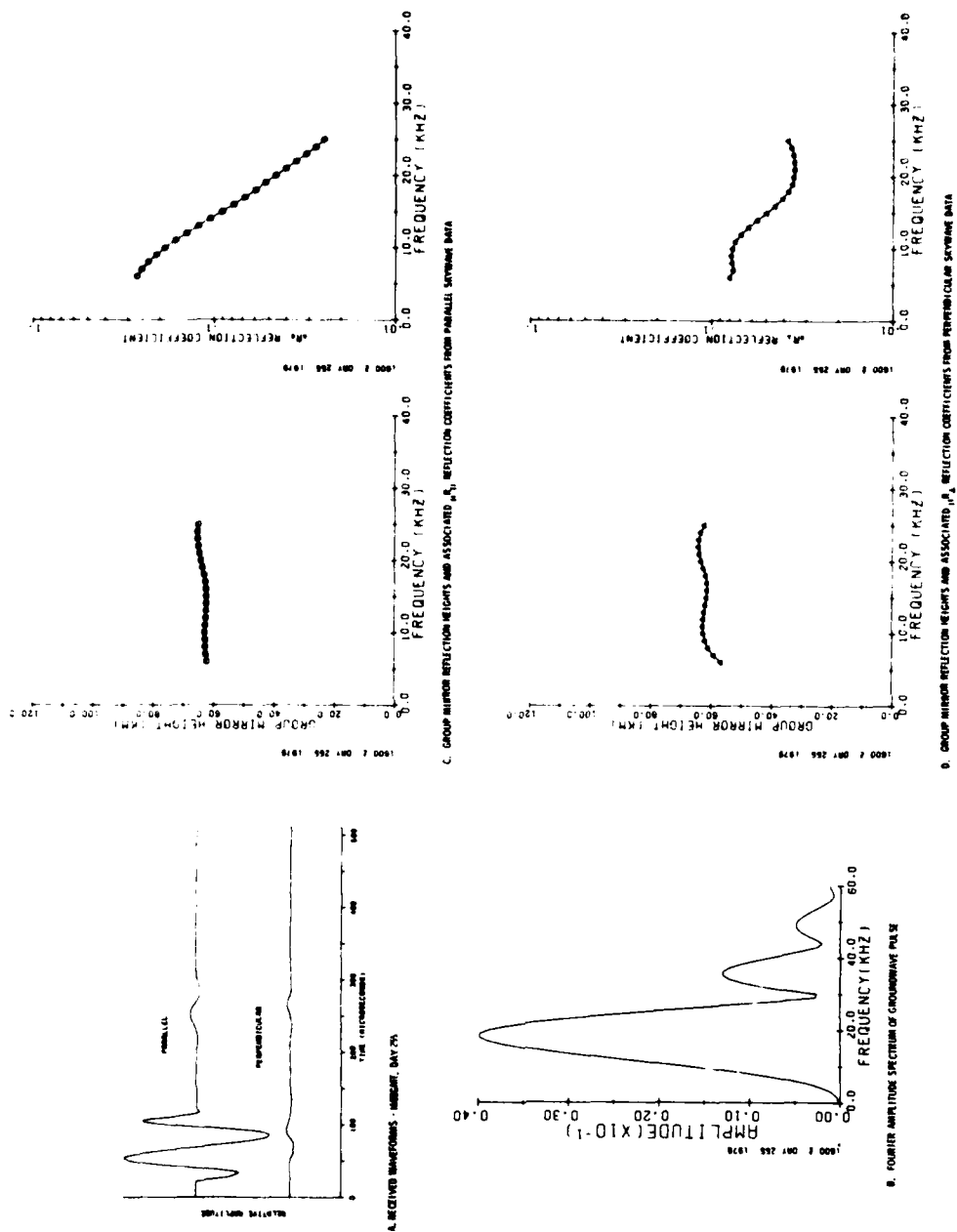


Figure 4. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 252 (9 Sept) - DAY 258 (15 Sept) 1979

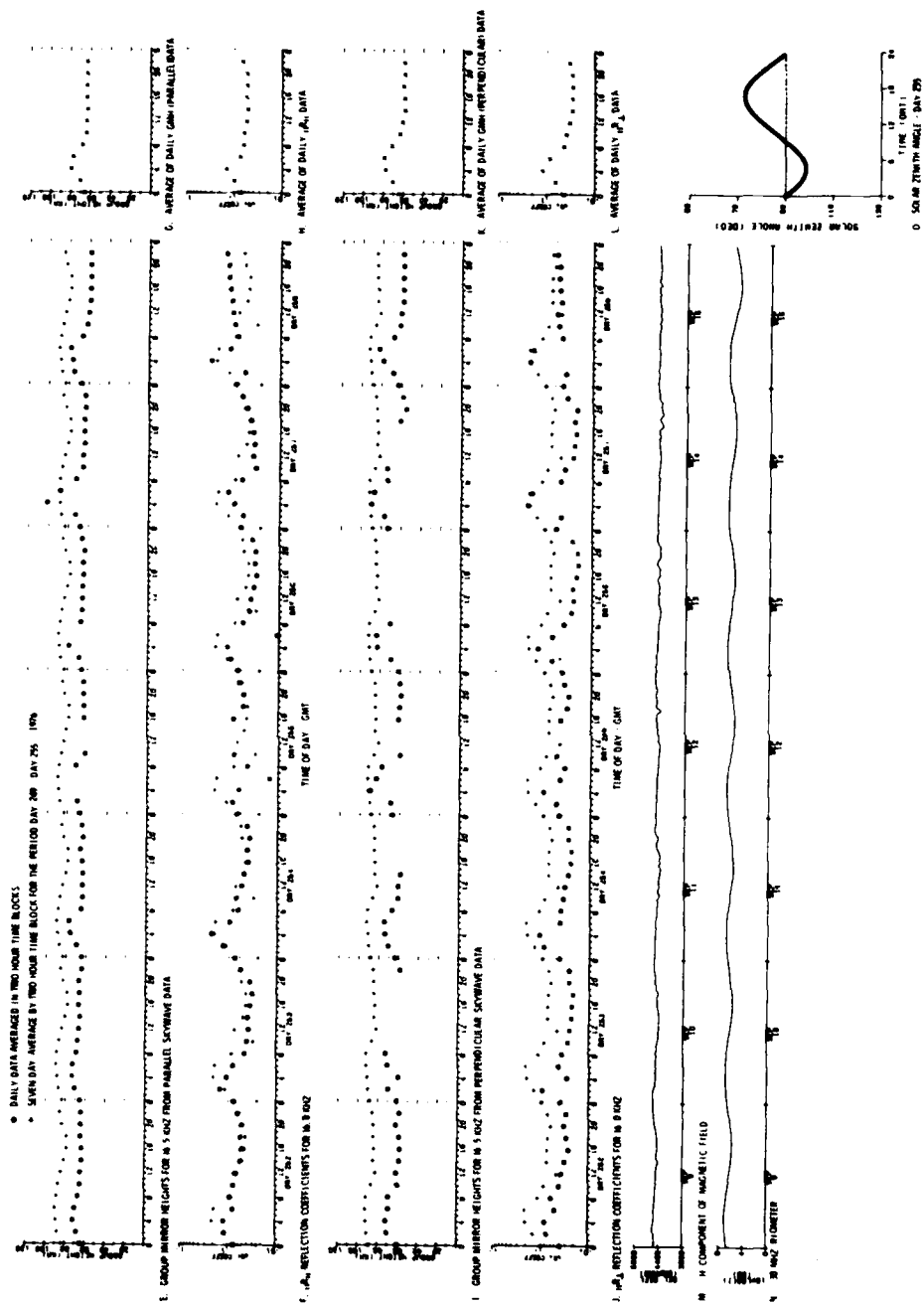


Figure 4. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 252 (9 Sept)–DAY 258 (15 Sept) 1979 (Cont.)

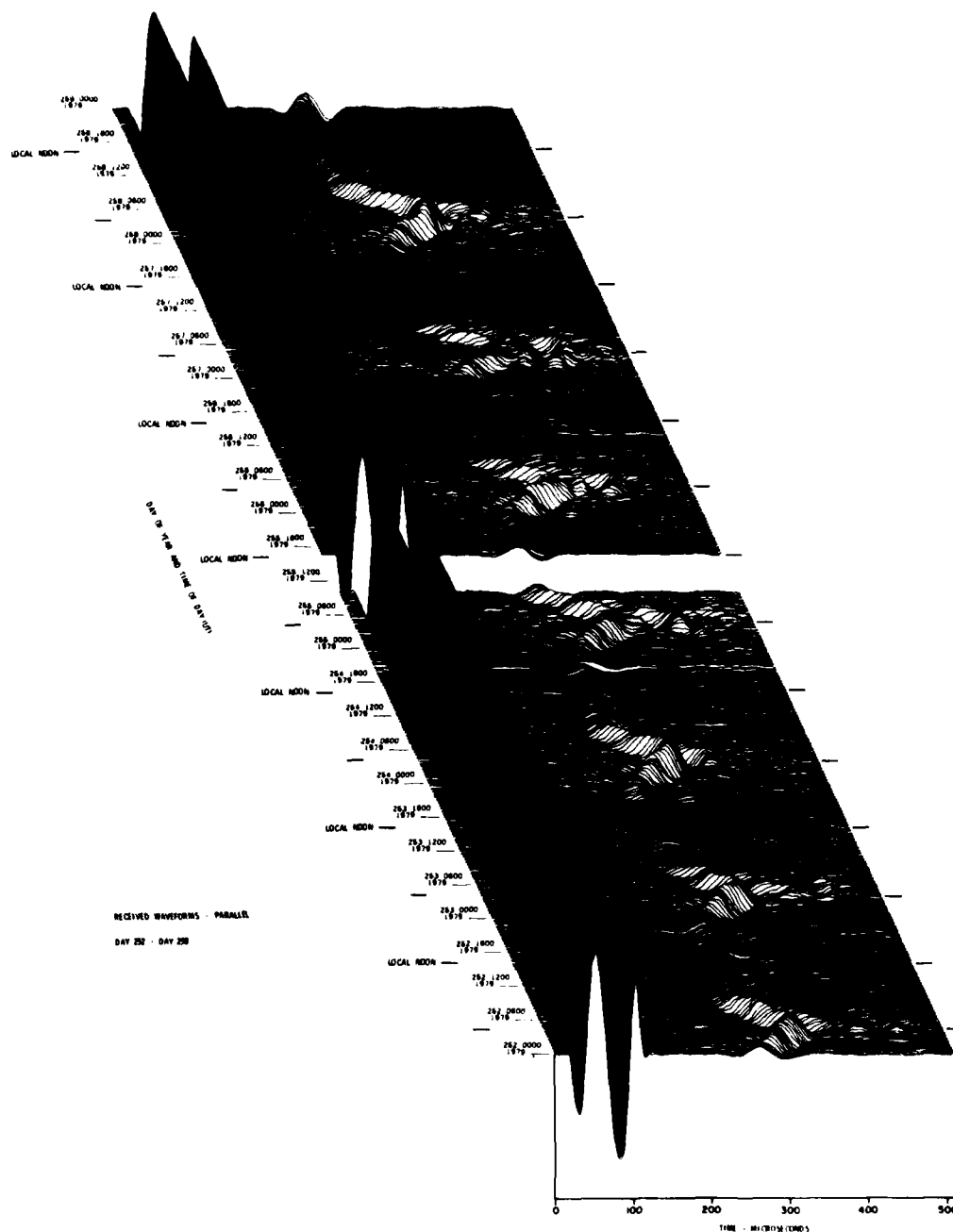


Figure 4. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 252 (9 Sept)-
DAY 258 (15 Sept) 1979 (Cont.)
Part R. || Waveform Display

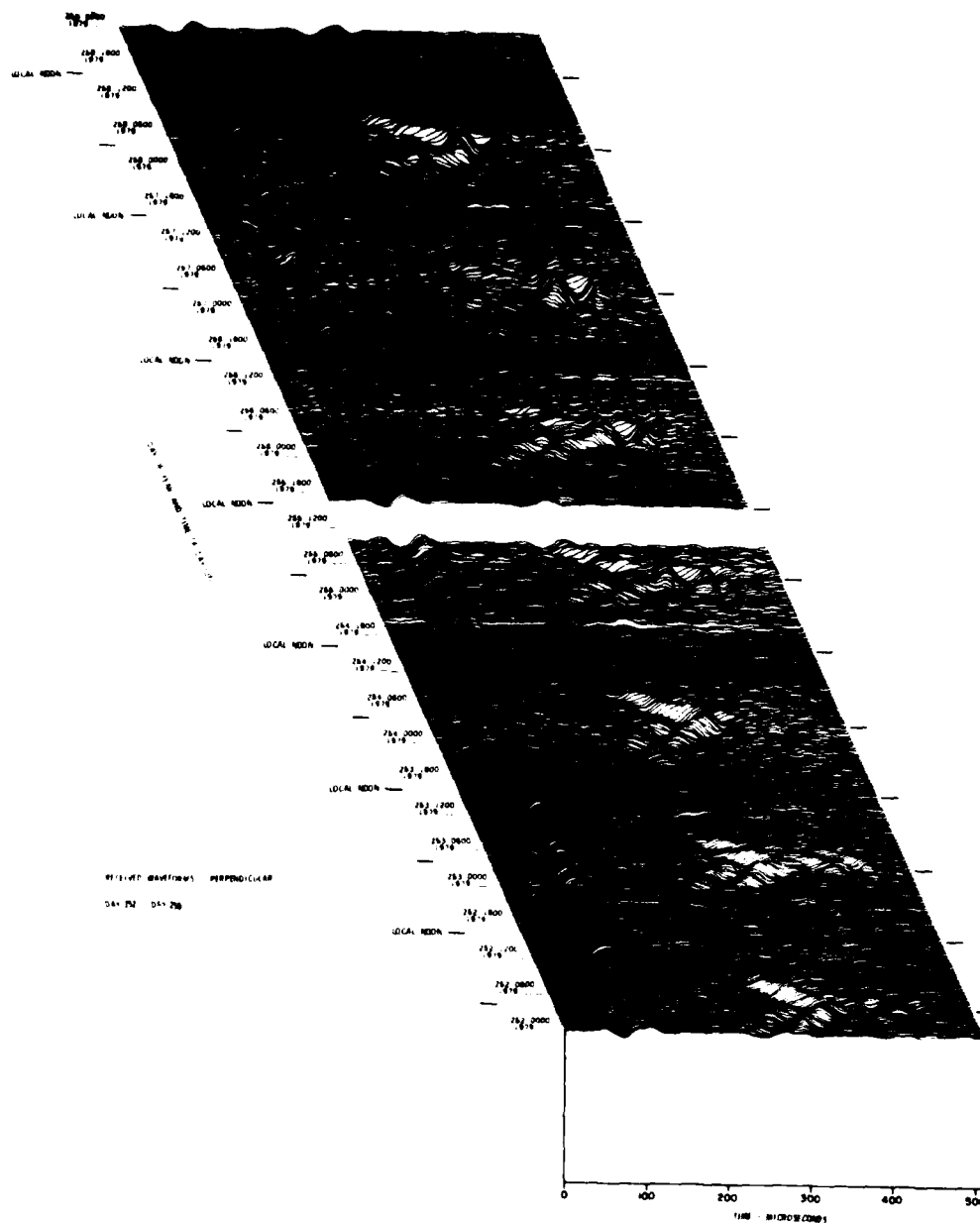


Figure 4. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 252 (9 Sept)-
DAY 258 (15 Sept) 1979 (Cont.)
Part S. 1 Waveform Display

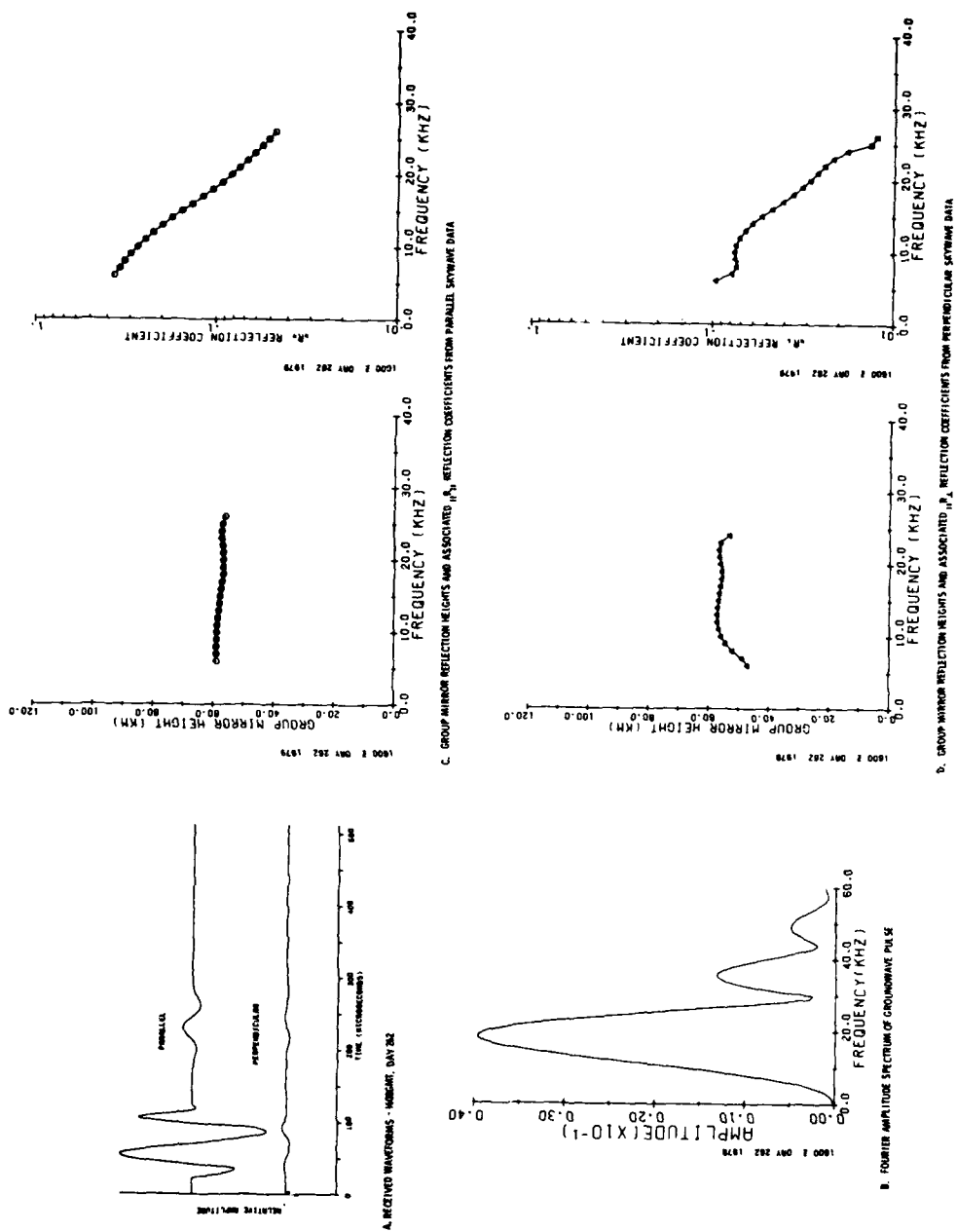


Figure 5. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 259 (16 Sept)-(22 Sept) 1979

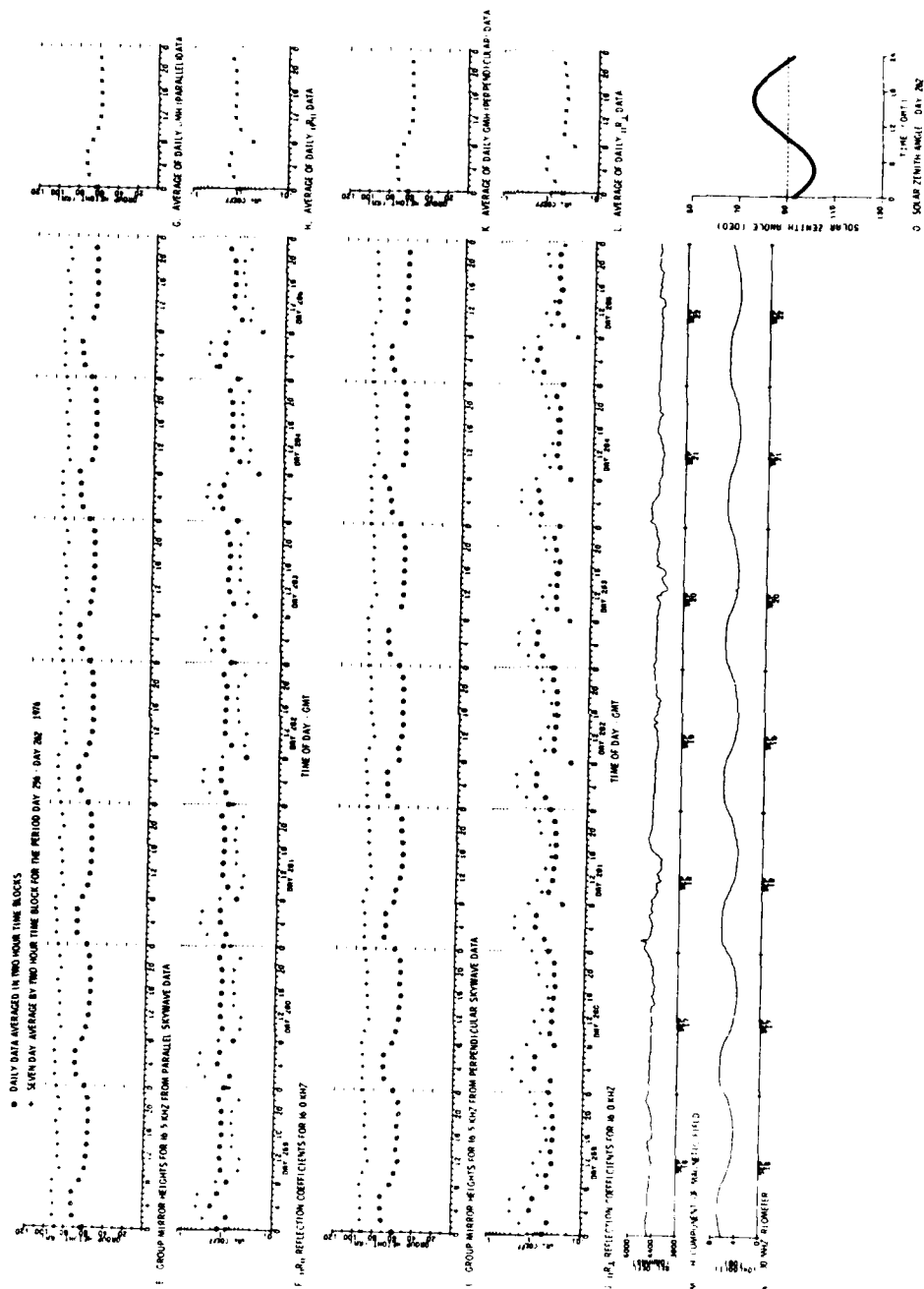


Figure 5. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 259 (16 Sept)-DAY 265 (22 Sept) 1979 (Cont.)

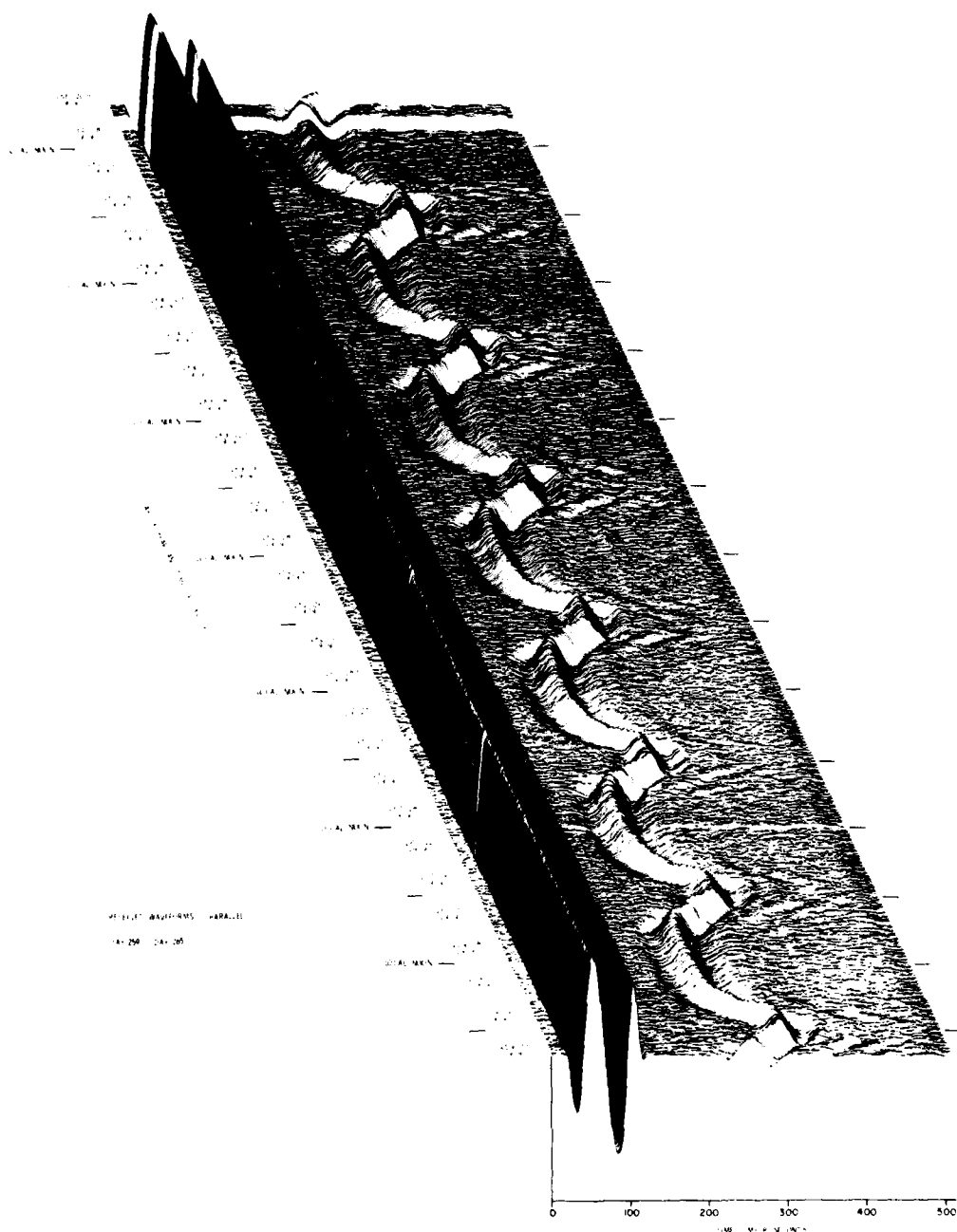


Figure 5. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 259 (16 Sept)—
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Part R. || Waveform Display

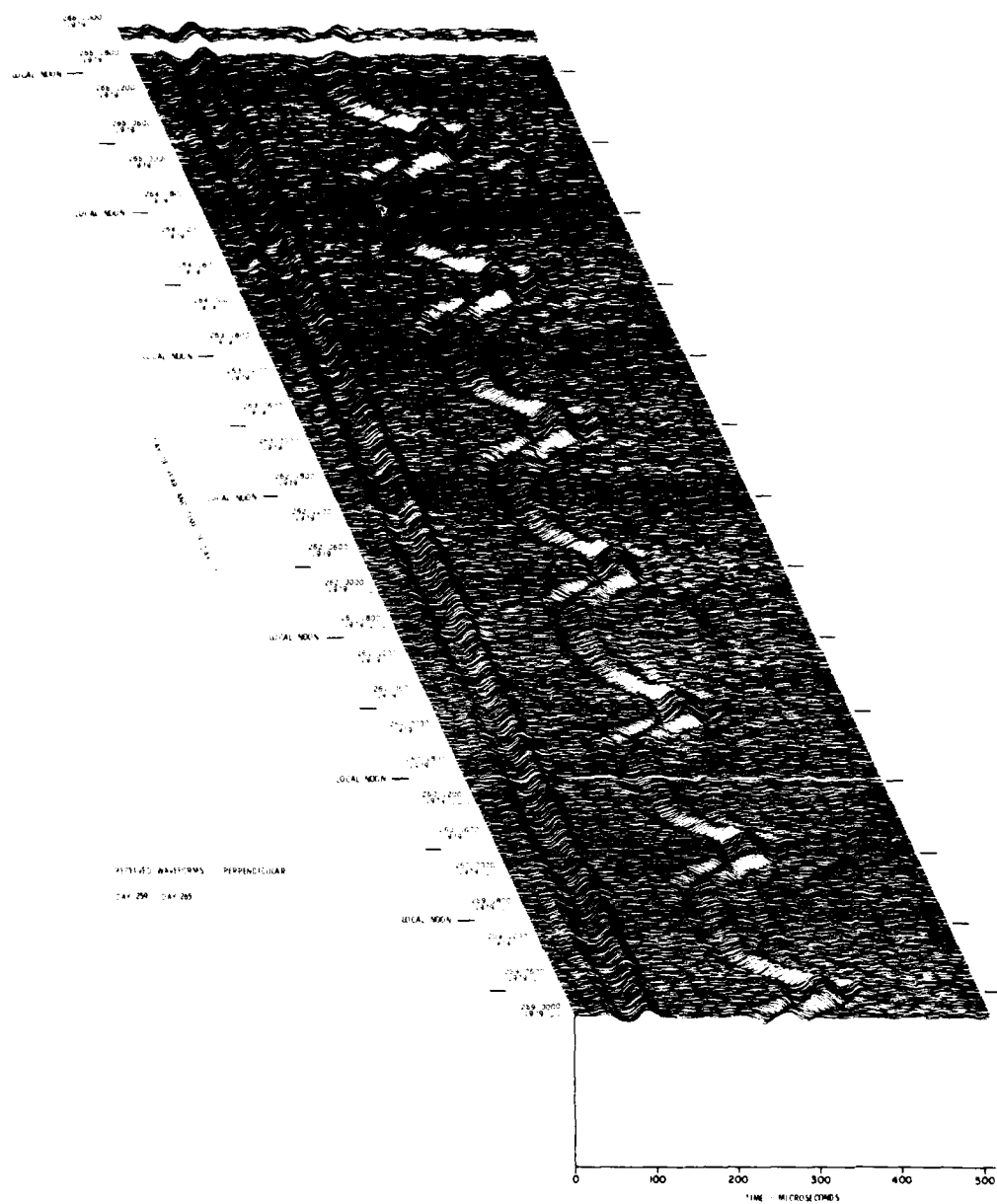


Figure 5. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 259 (16 Sept)-
DAY 265 (22 Sept) 1979 (Cont.)
Part S. 1 Waveform Display

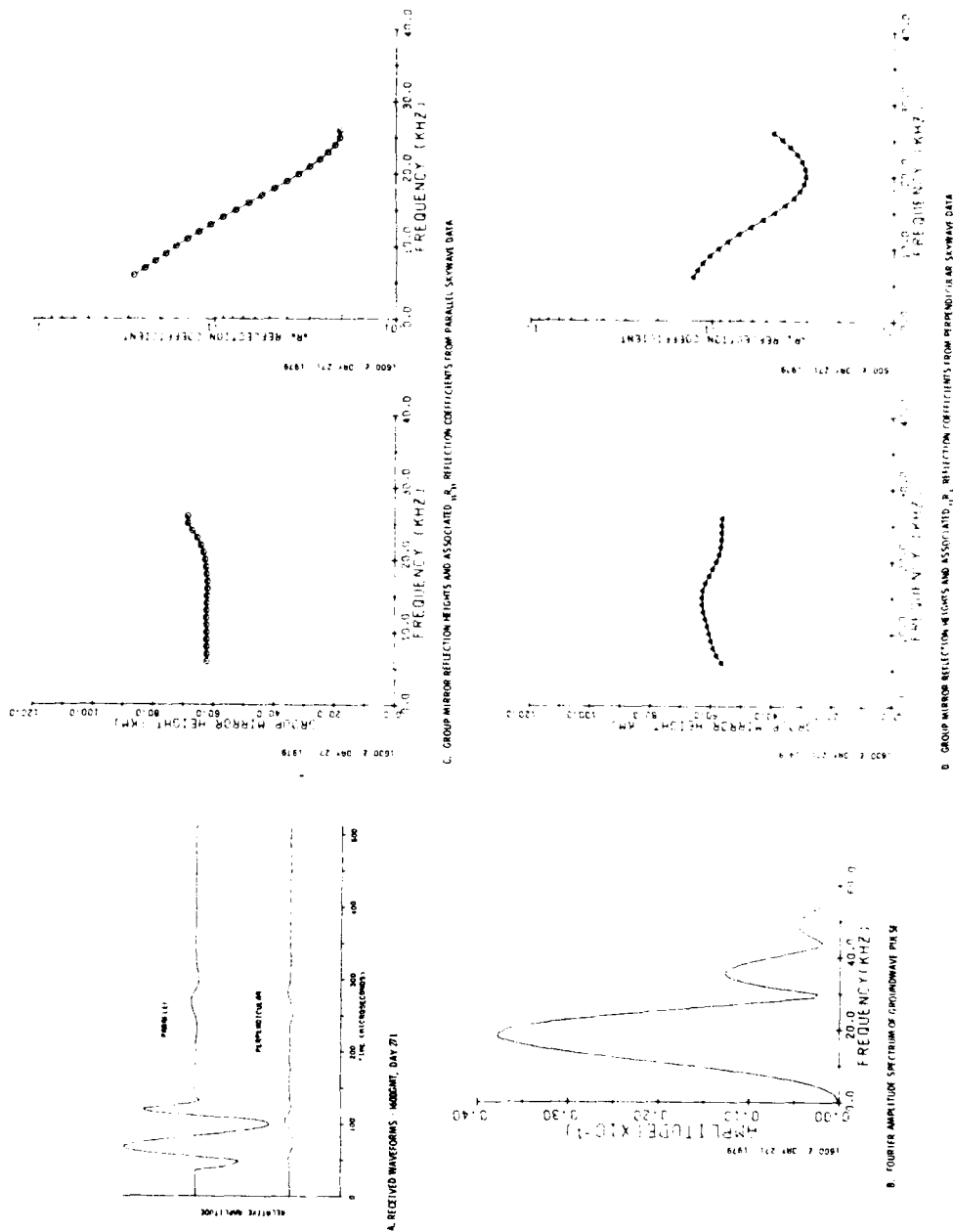


Figure 6. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 266 (23 Sept)–DAY 272 (29 Sept) 1979

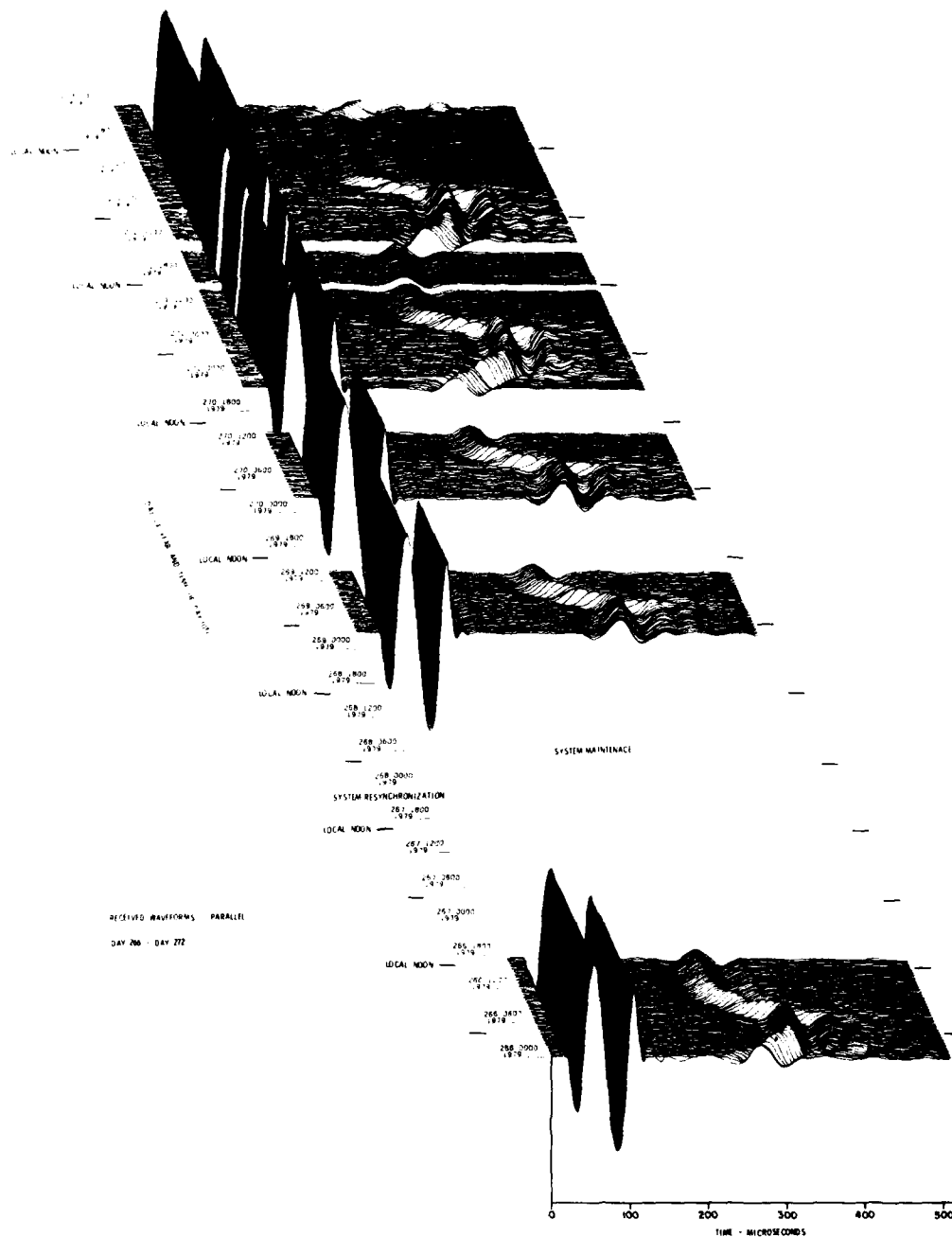


Figure 6. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 266 (23 Sept)–DAY 272 (29 Sept) 1979 (Cont.)
Part R. || Waveform Display

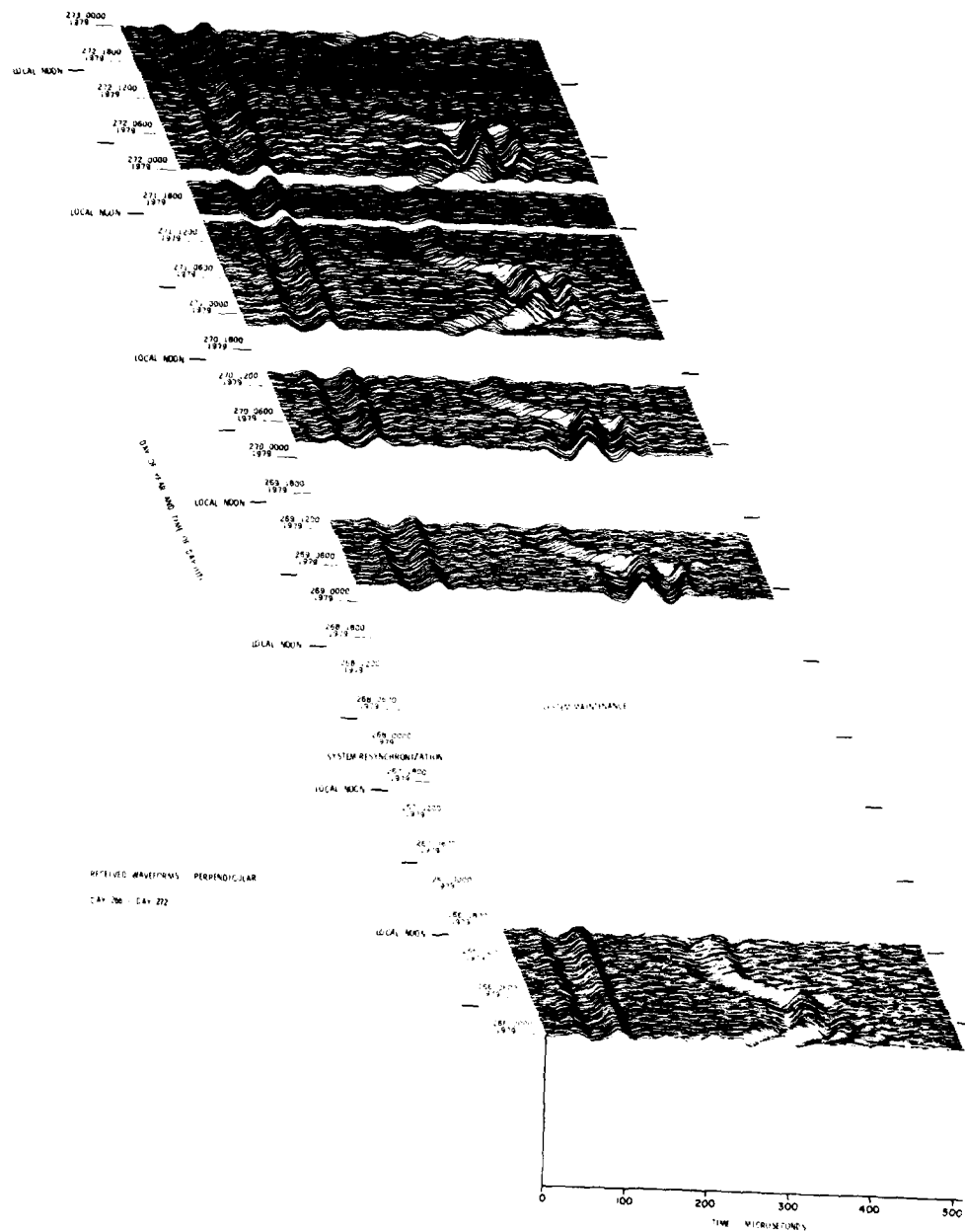


Figure 6. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 266 (23 Sept) - DAY 272 (29 Sept) 1979 (Cont.)
Part S. 1 Waveform Display

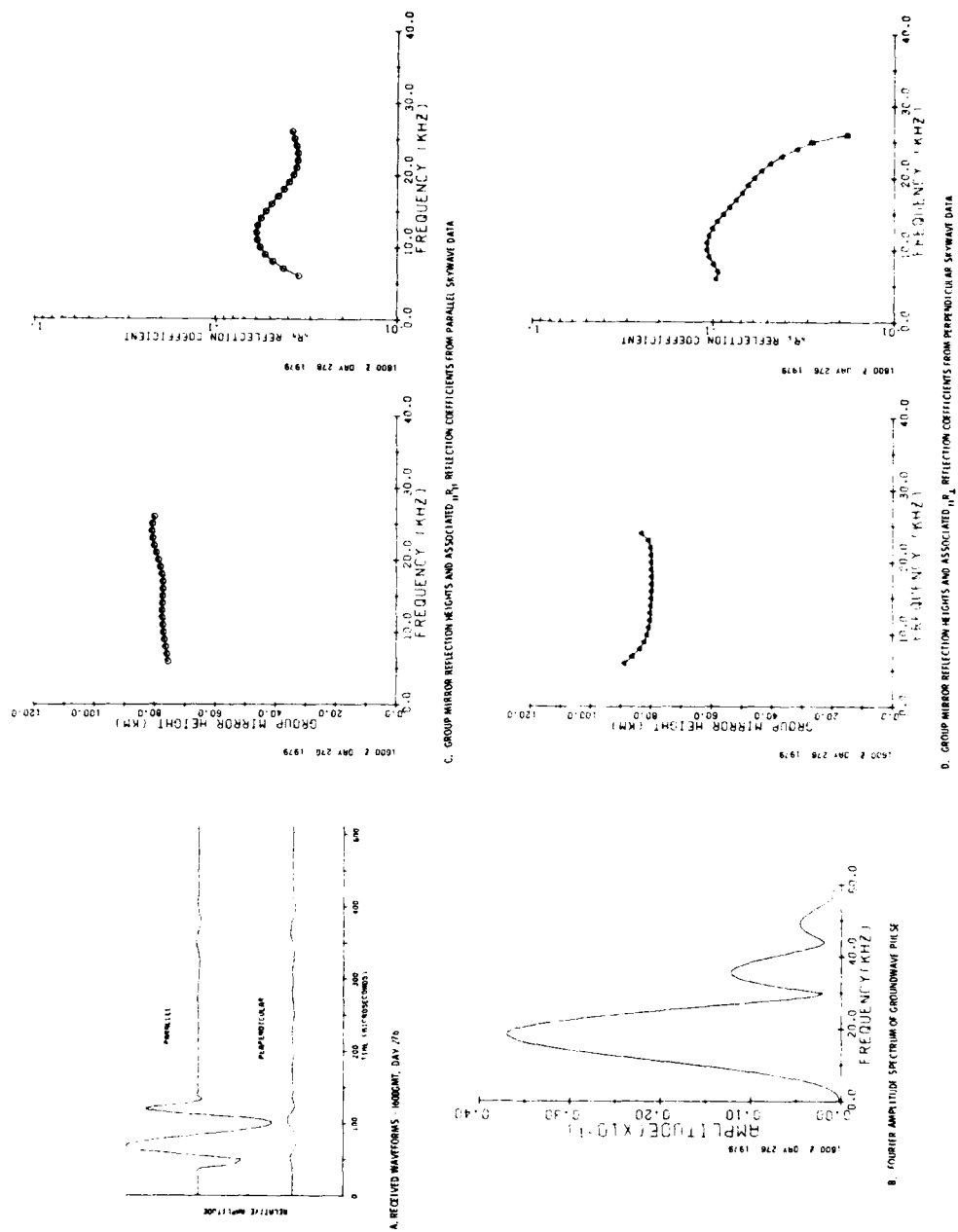


Figure 7. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 273 (30 Sept)–DAY 279 (6 Oct) 1979

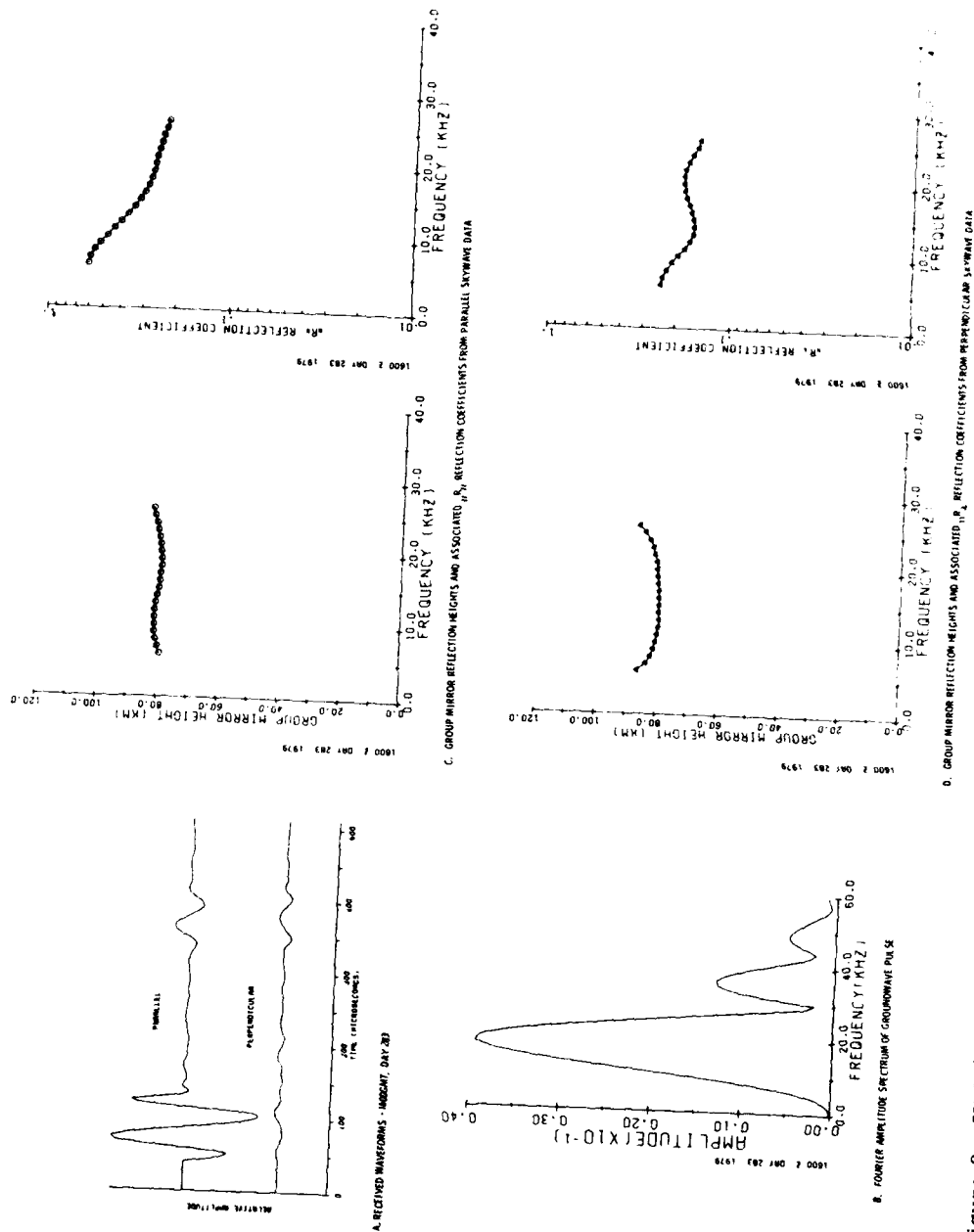


Figure 8. VI.F/LF Reflectivity Data for the Polar Ionosphere, DAY 280 (7 Oct)-DAY 286 (13 Oct) 1979

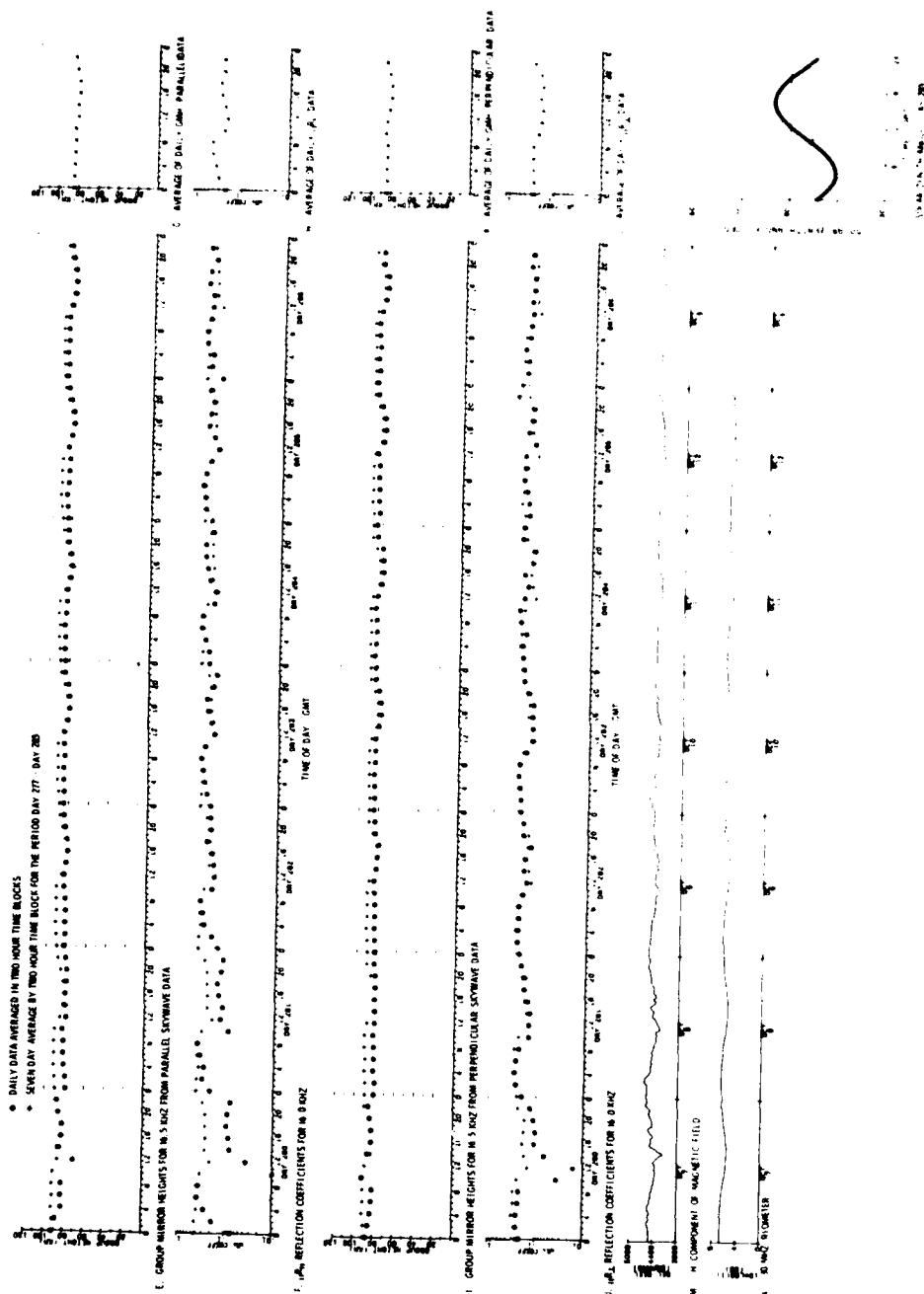


Figure 8. VLF/I.F. Reflectivity Data for the Polar Ionosphere, DAY 280 (7 Oct) - DAY 286 (13 Oct) 1979 (Cont.)

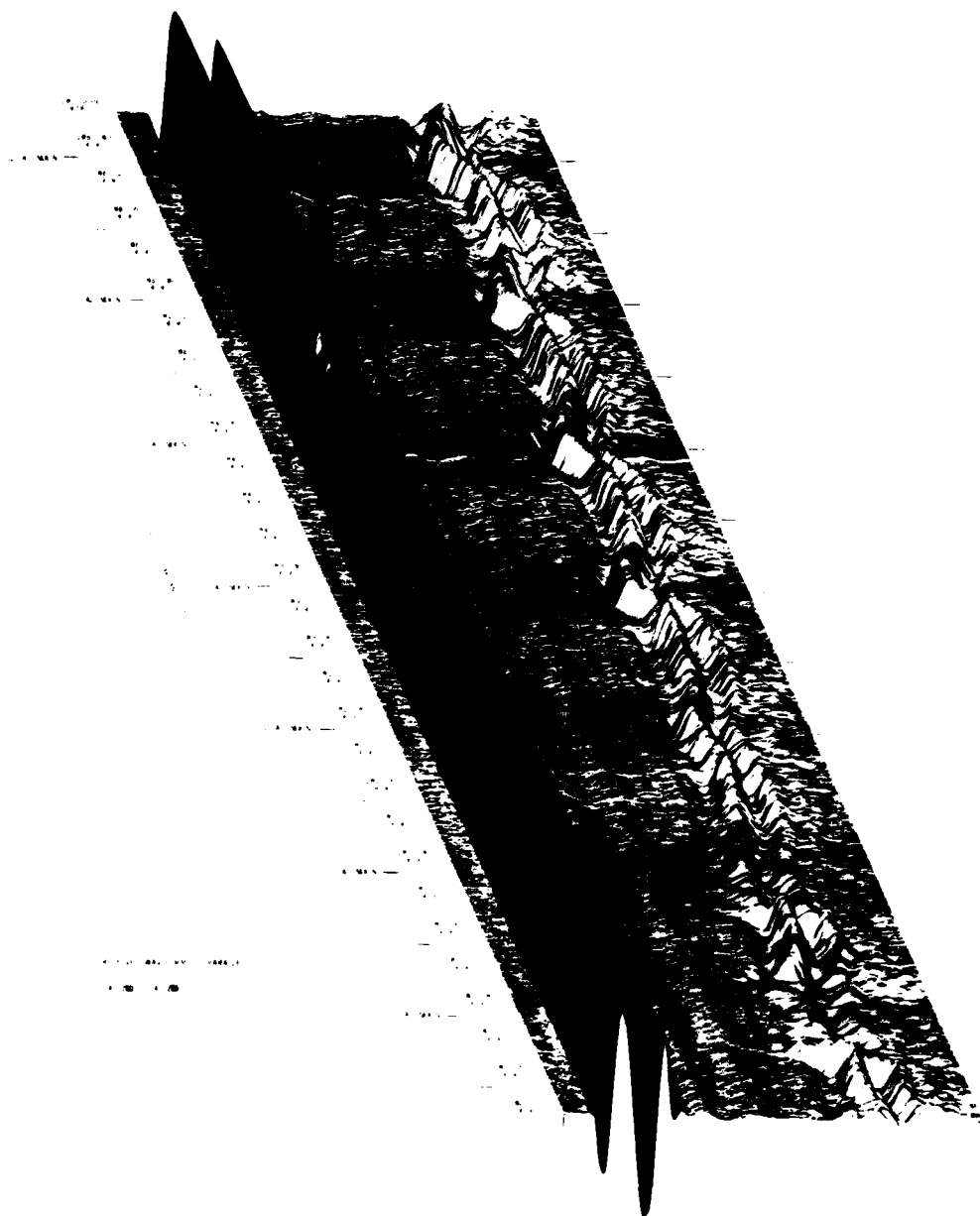


Figure 8. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 280 (7 Oct) -
 DAY 286 (13 Oct) 1979 (Cont.)
 Part R. Waveform Display

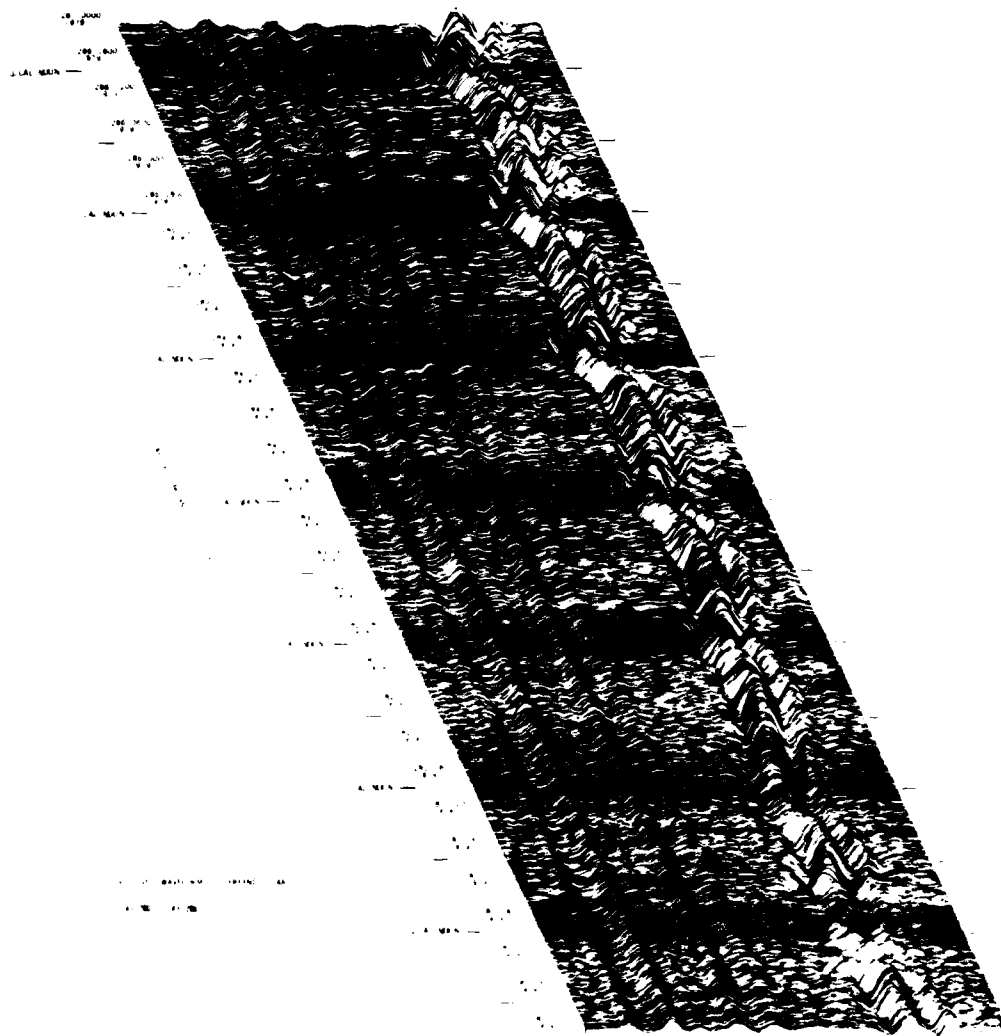


Figure 8. VLF-LF Reflectivity Data for the Polar Ionosphere, DAY 280 (7 Oct)-
 DAY 286 (13 Oct) 1979 (Cont.)
 Part S. , Waveform Display

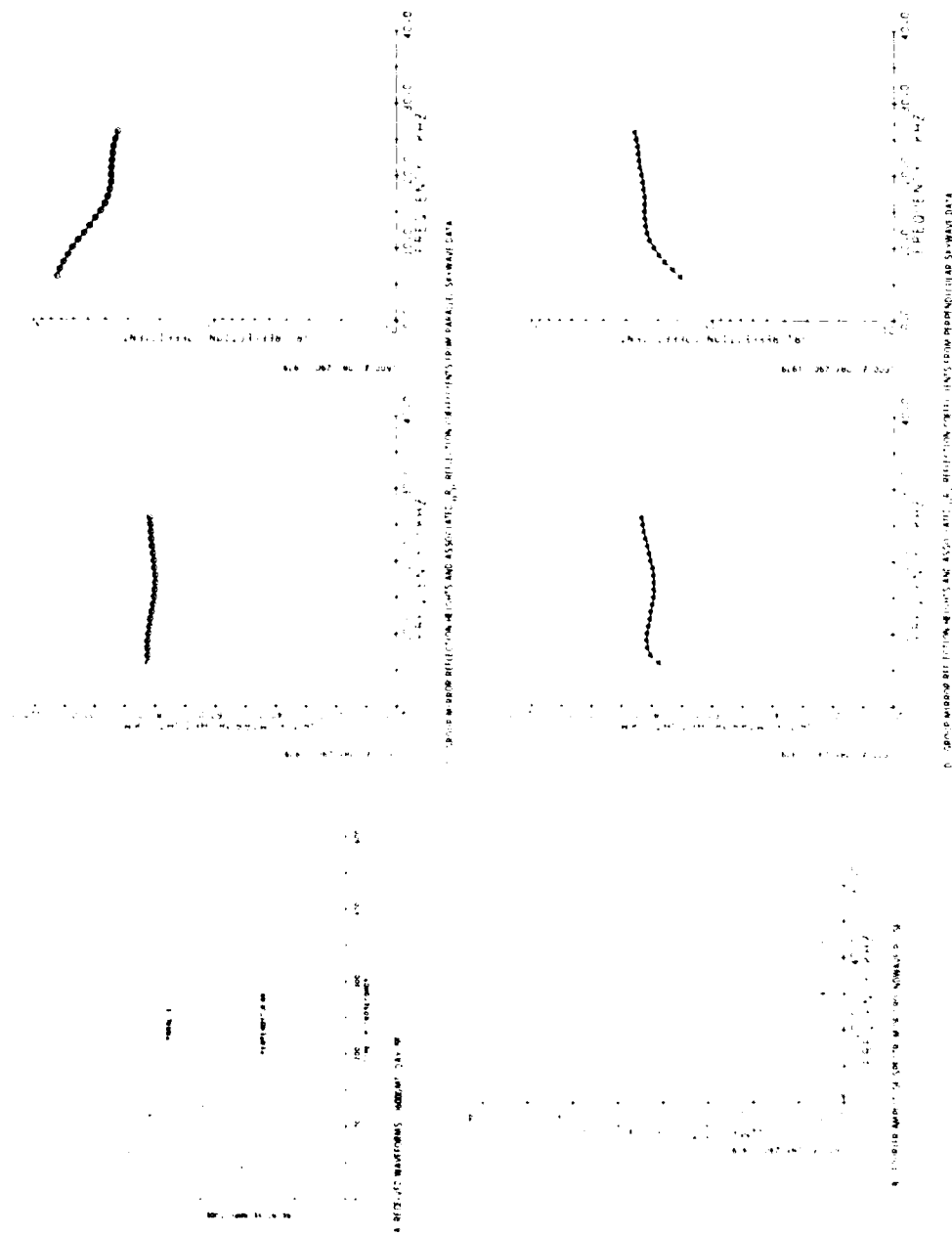
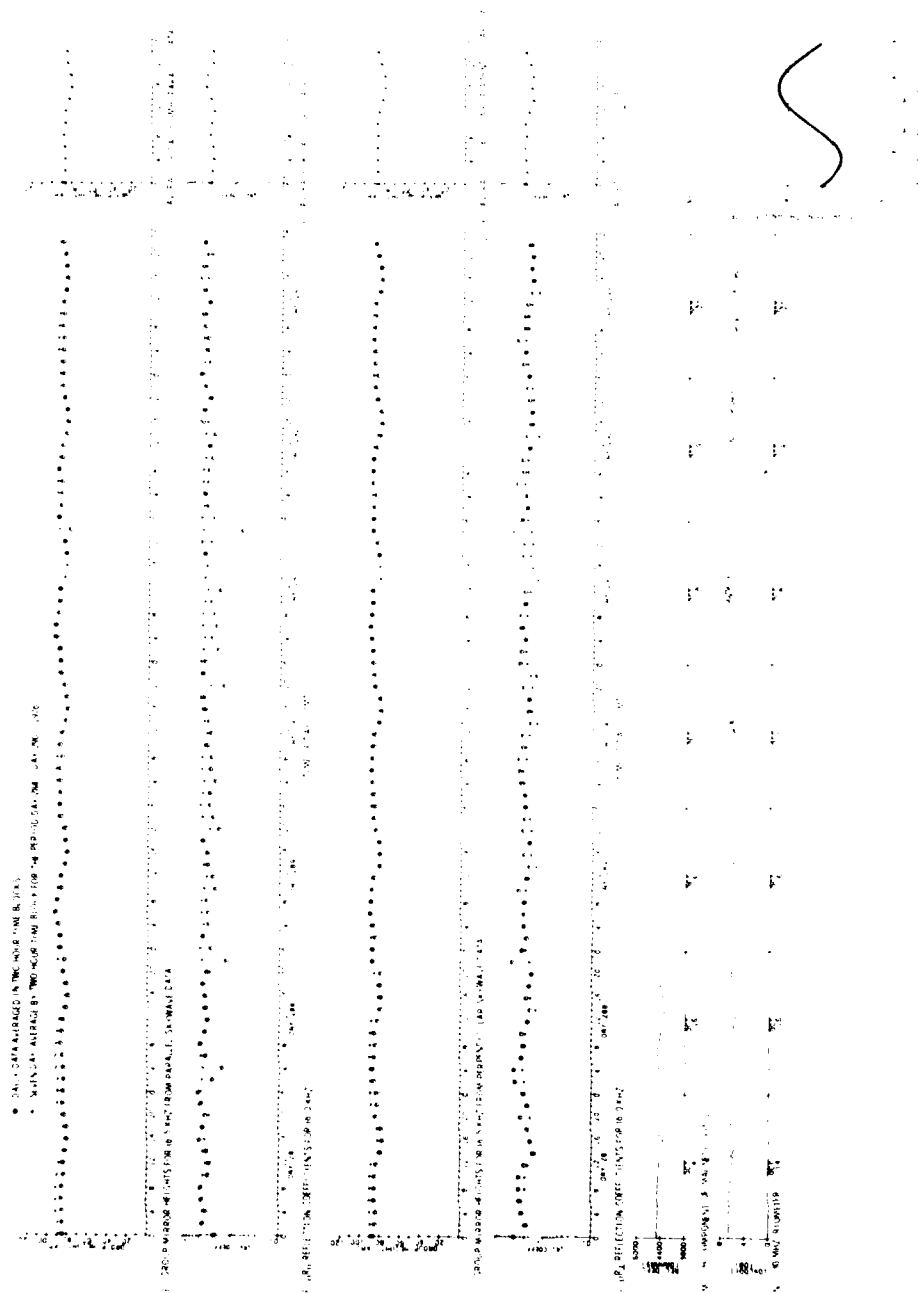


Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 287 (14 Oct)-DAY 293 (20 Oct) 1979



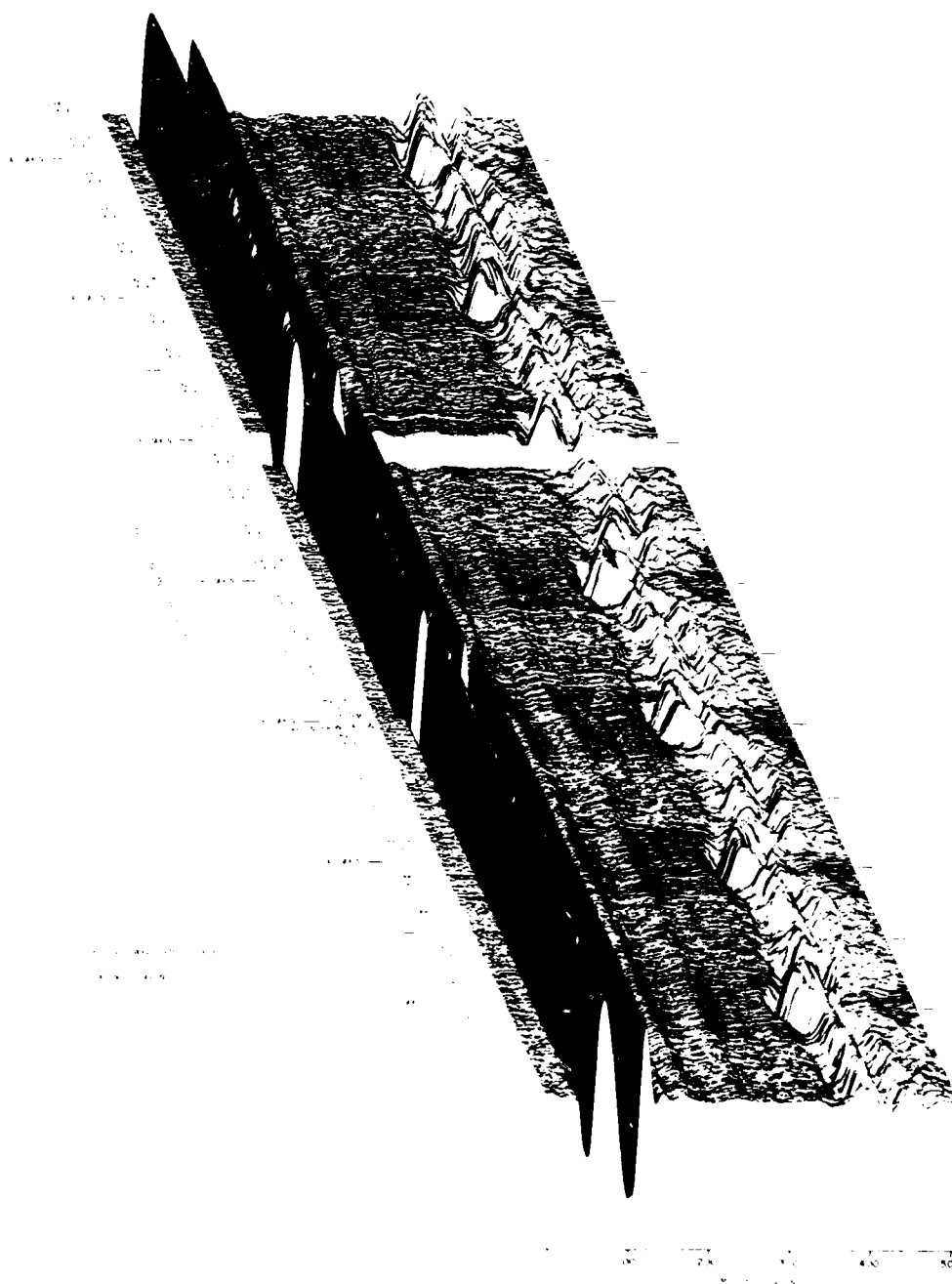


Figure 9. VLF/ELF Reflectivity Data for the Polar Ionosphere, DAY 287 (14 Oct)—
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 Part R. Waveform Display

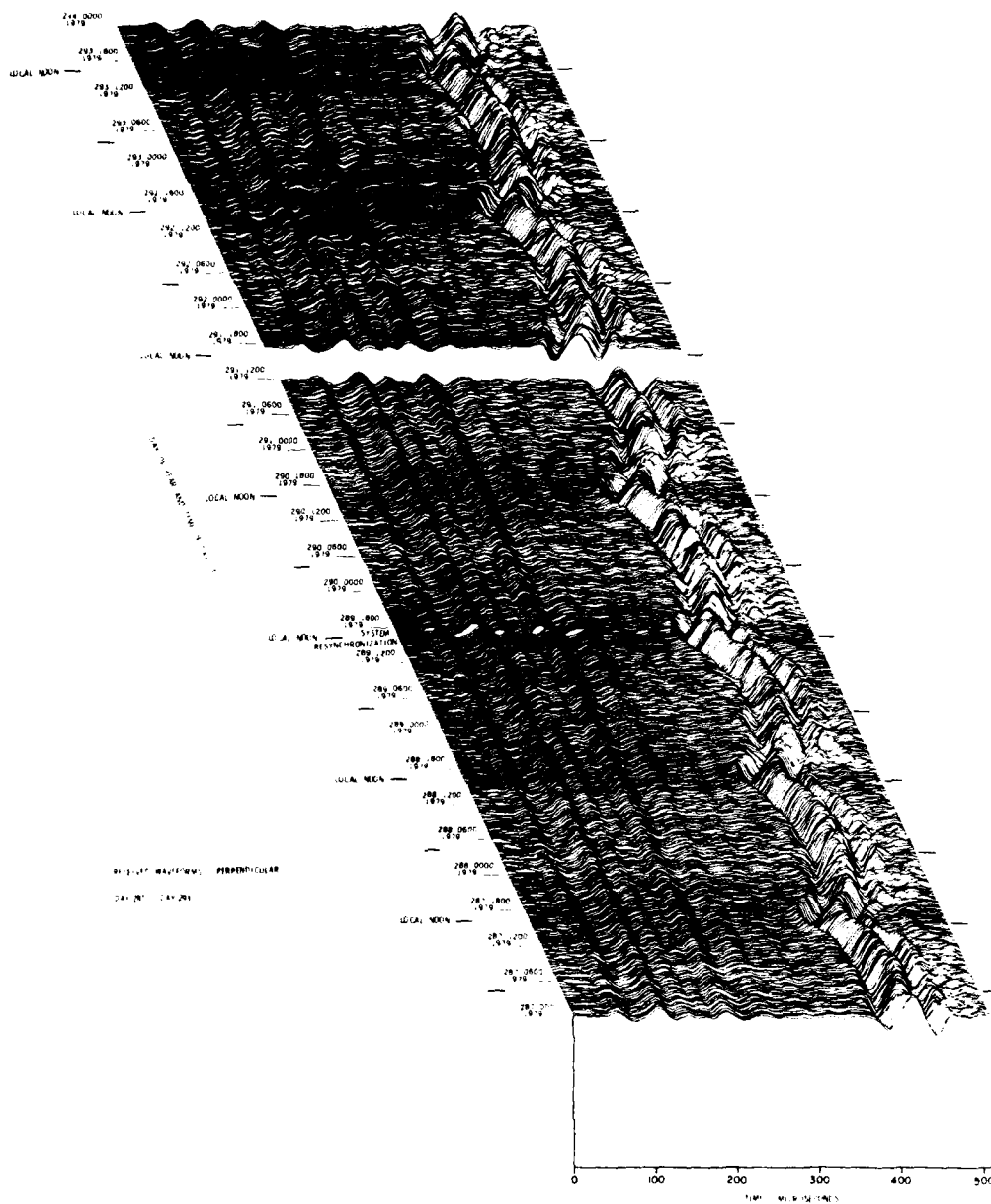


Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 287 (14 Oct)-
DAY 293 (20 Oct) 1979 (Cont.)
Part S. 1 Waveform Display

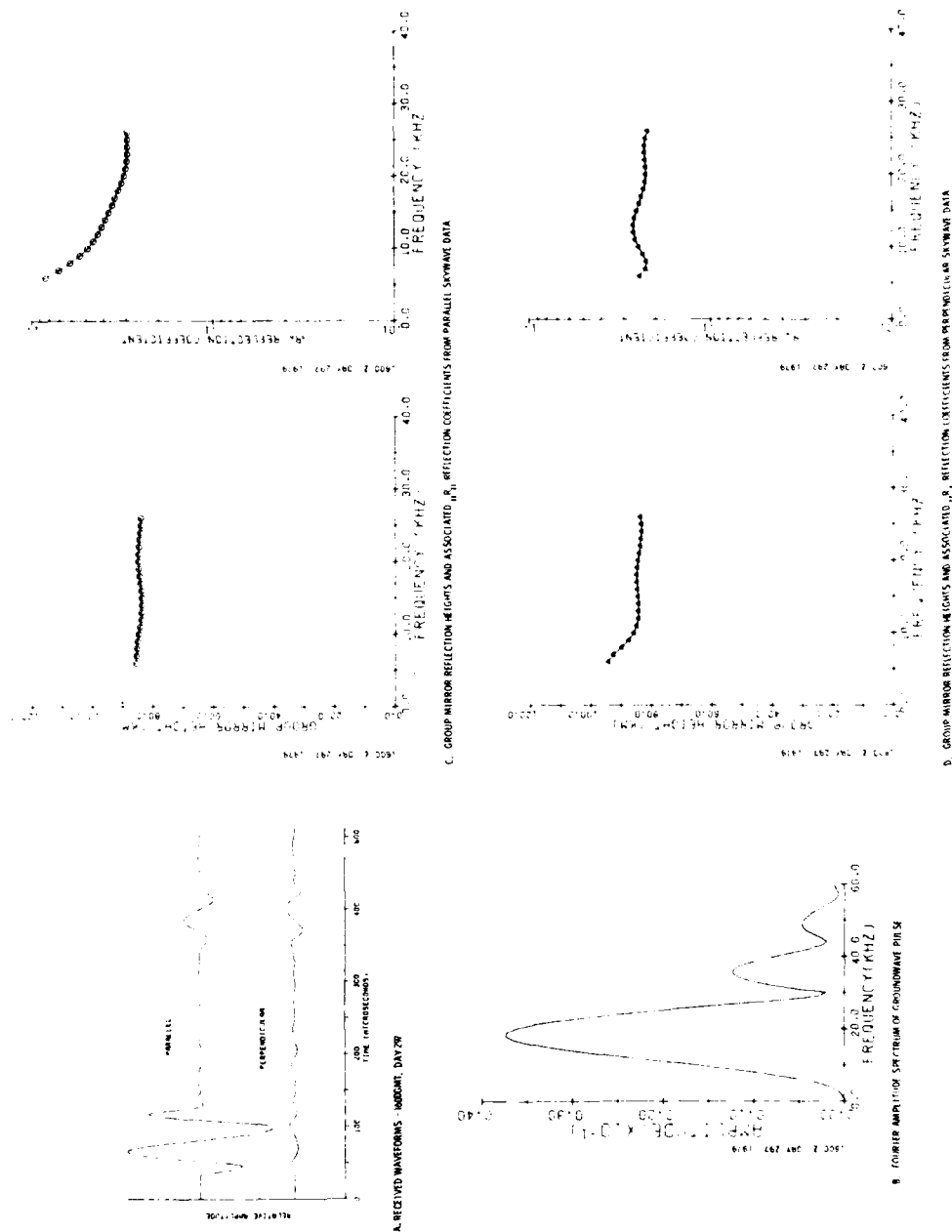


Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 294 (21 Oct)-DAY 300 (27 Oct) 1979

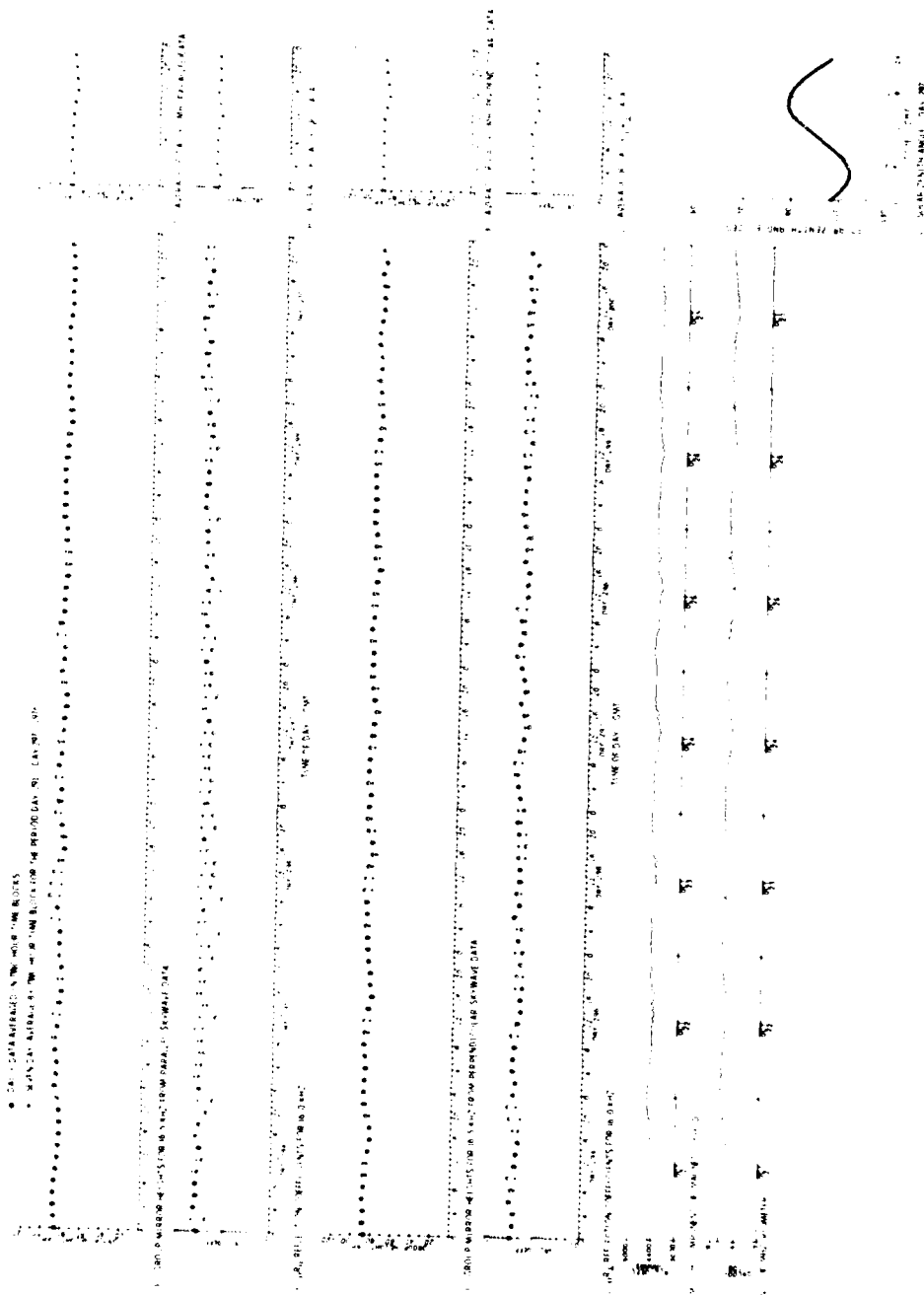


Figure 10. VI.F/LF Reflectivity Data for the Polar Ionosphere, DAY 294 (21 Oct)-DAY 300 (27 Oct) 1979 (Cont.)

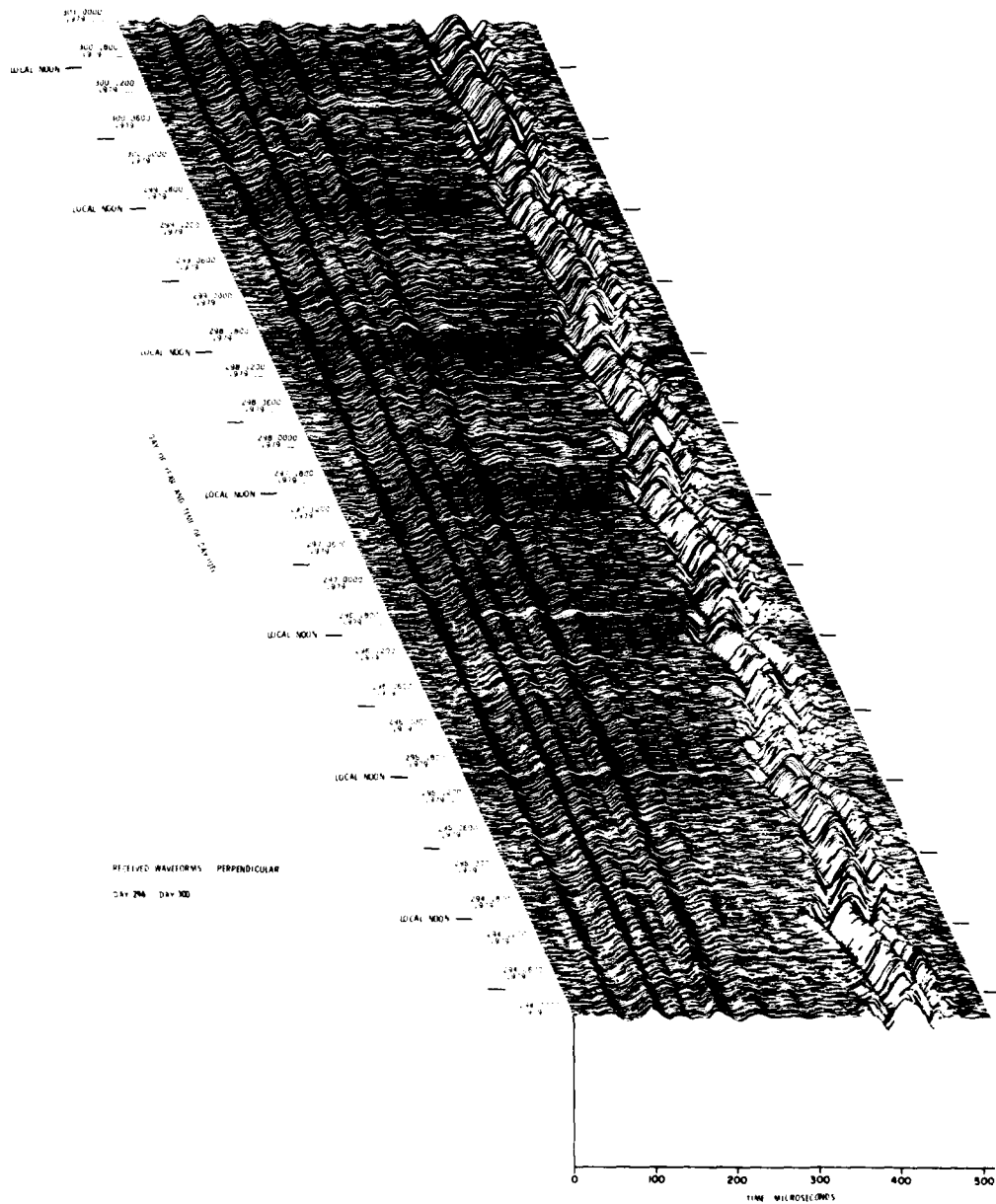


Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 294 (21 Oct)-
DAY 300 (27 Oct) 1979 (Cont.)
Part S. 1 Waveform Display

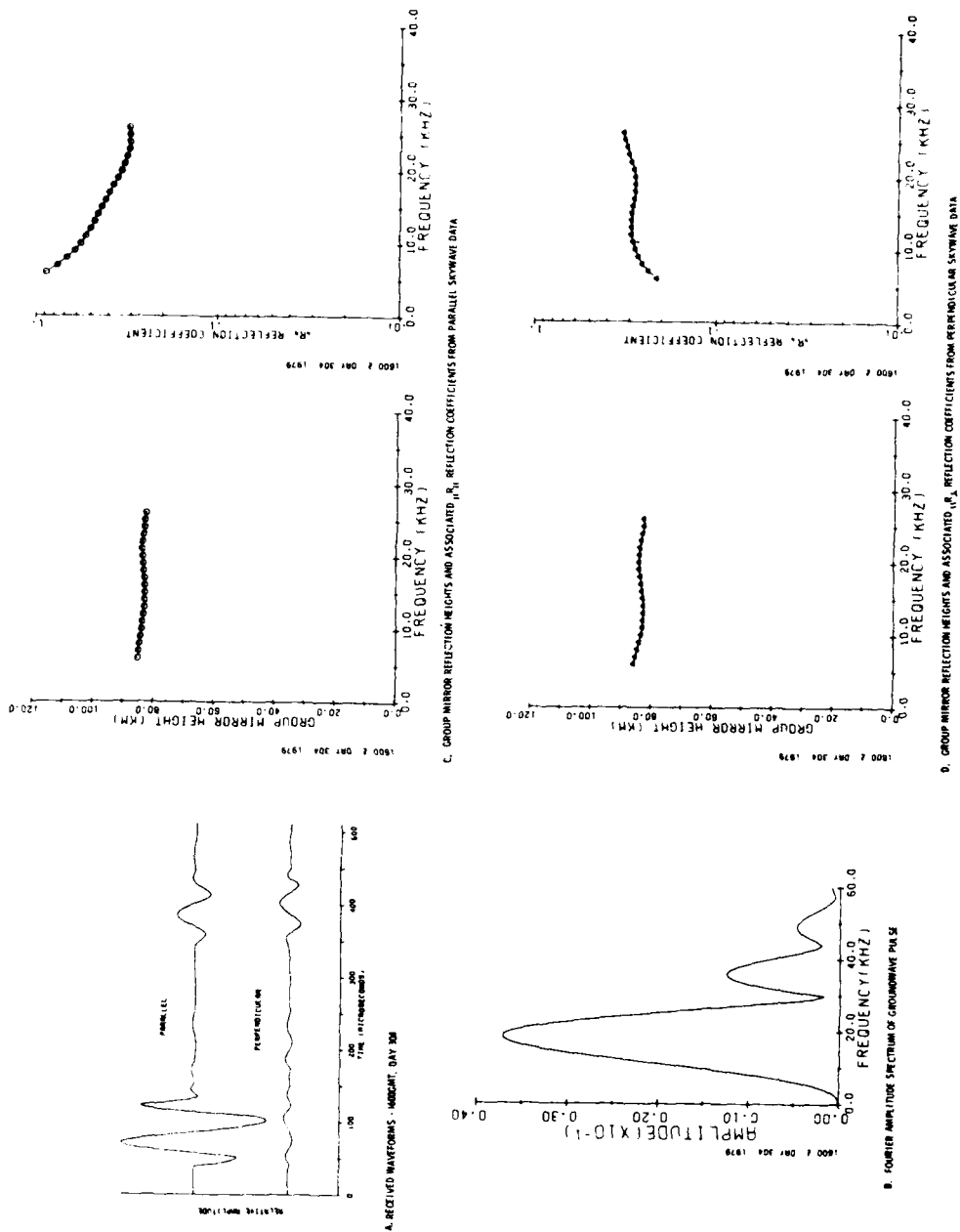


Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 301 (28 Oct)-DAY 307 (3 Nov) 1979

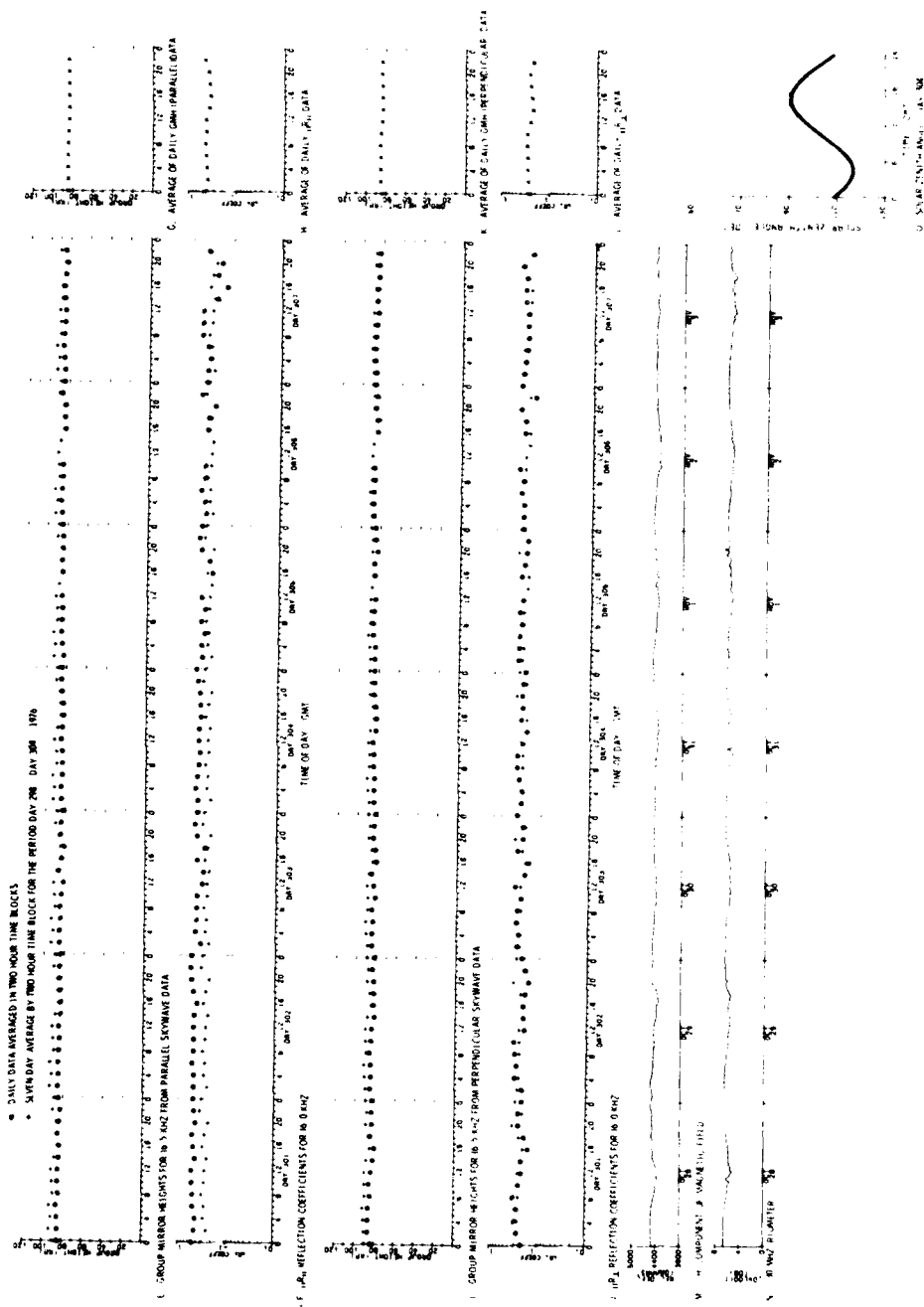


Figure 11. VI.F/I.F Reflectivity Data for the Polar Ionosphere, DAY 301 (28 Oct)-DAY 307 (3 Nov) 1979 (Cont.)

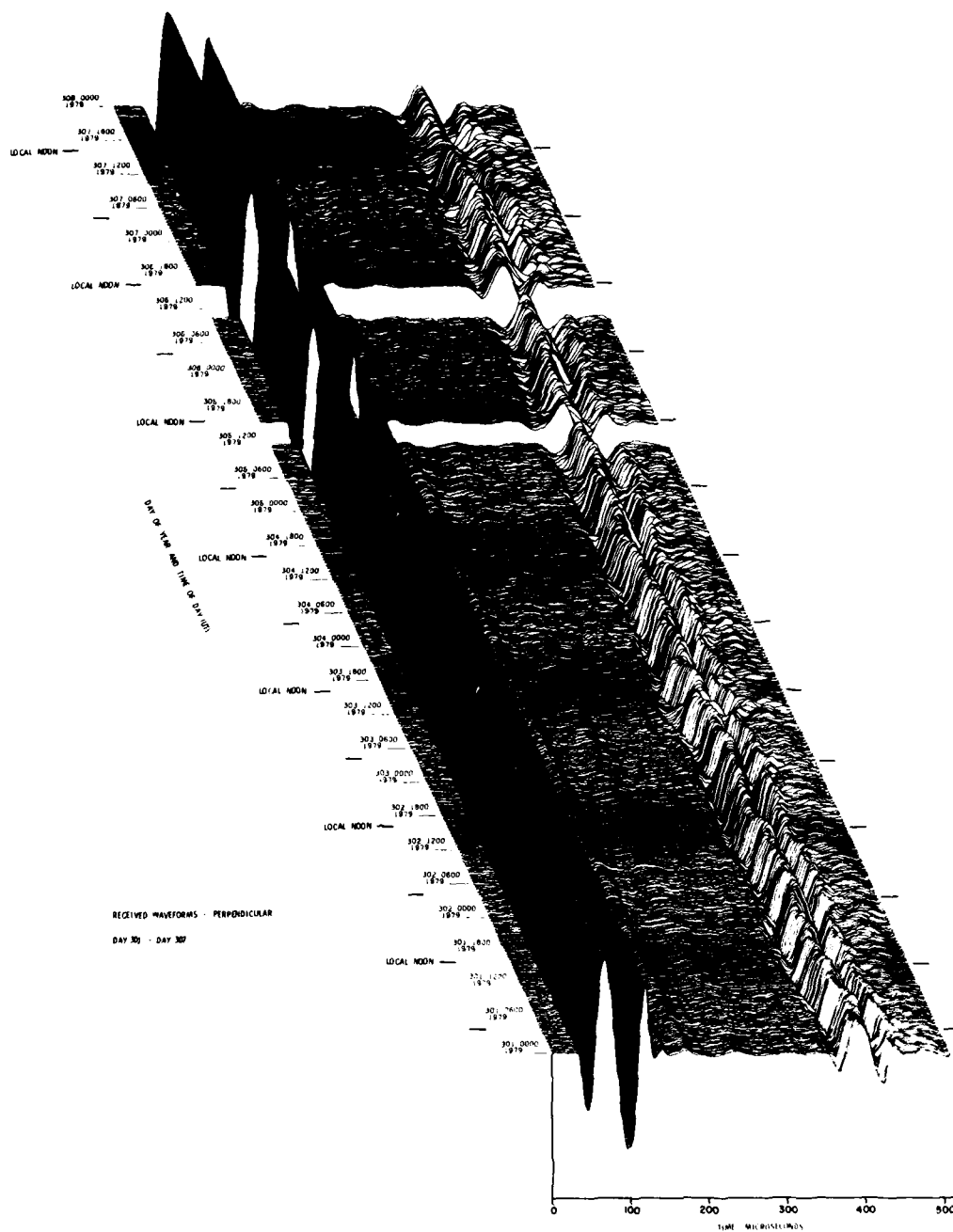


Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 301 (28 Oct)-
DAY 307 (3 Nov) 1979 (Cont.)
Part R. || Waveform Display

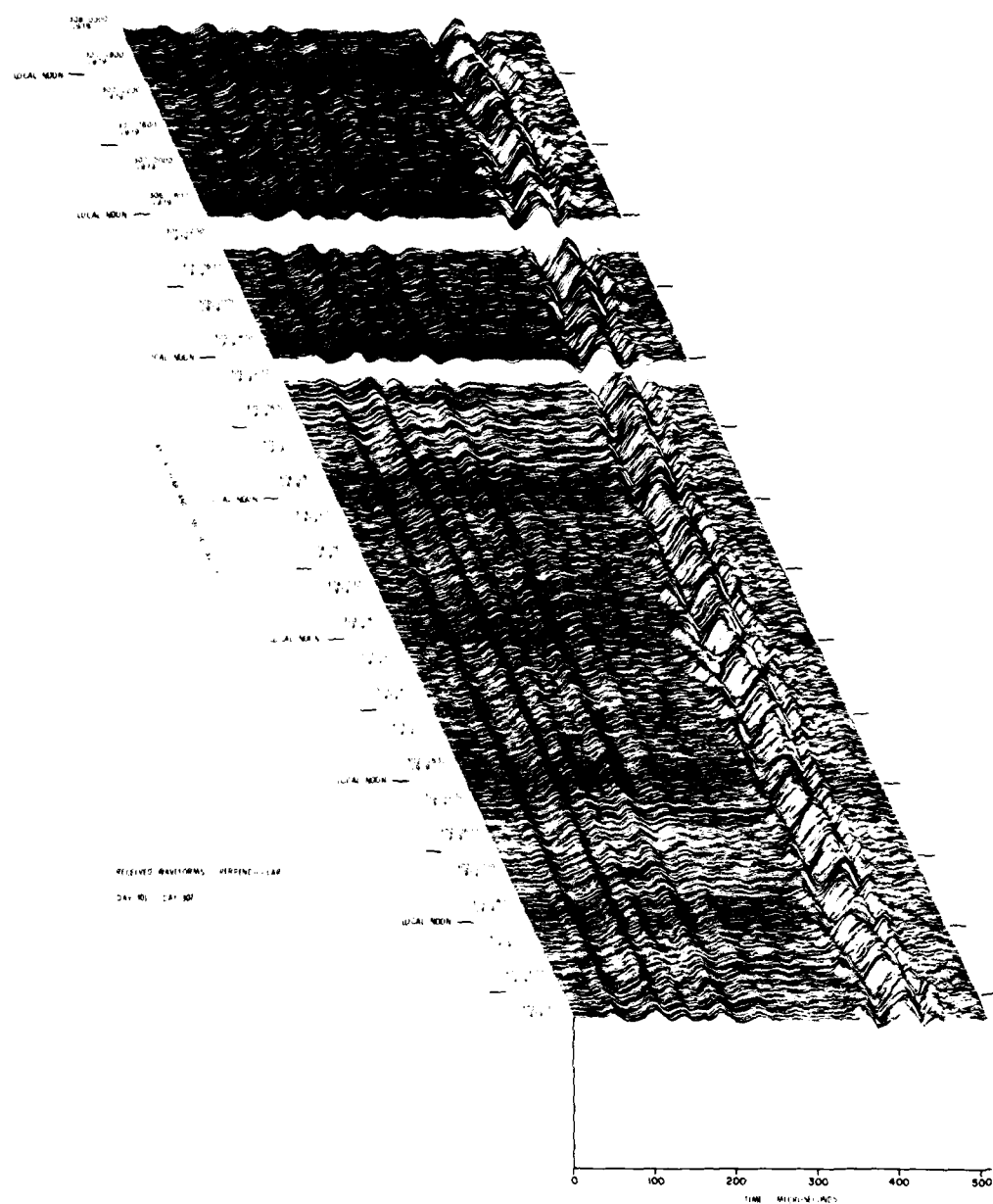


Figure 11. VLF/1F Reflectivity Data for the Polar Ionosphere, DAY 301 (28 Oct)-
DAY 307 (3 Nov) 1979 (Cont.)
Part S. 1 Waveform Display

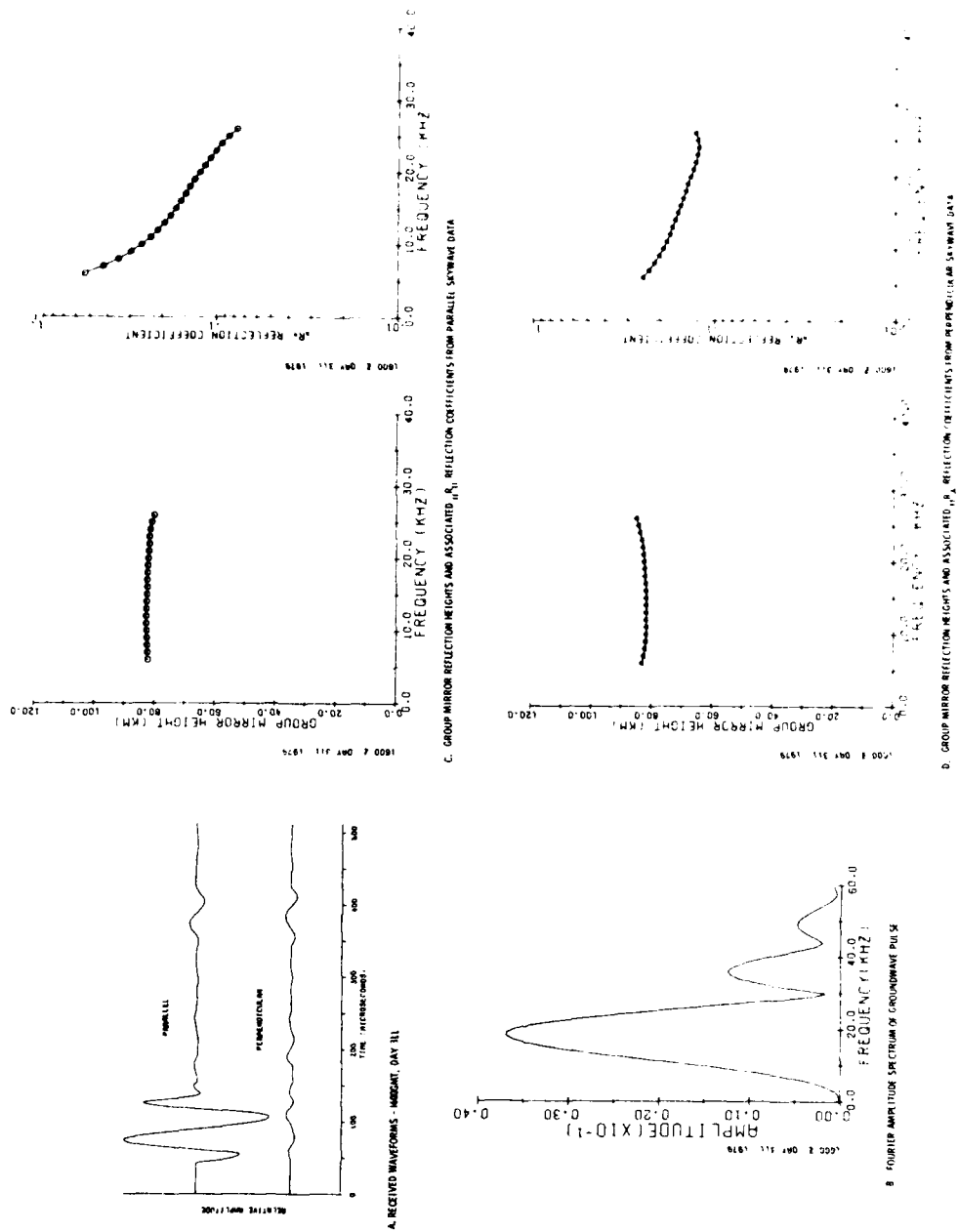


Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 308 (4 Nov)–DAY 314 (10 Nov) 1979

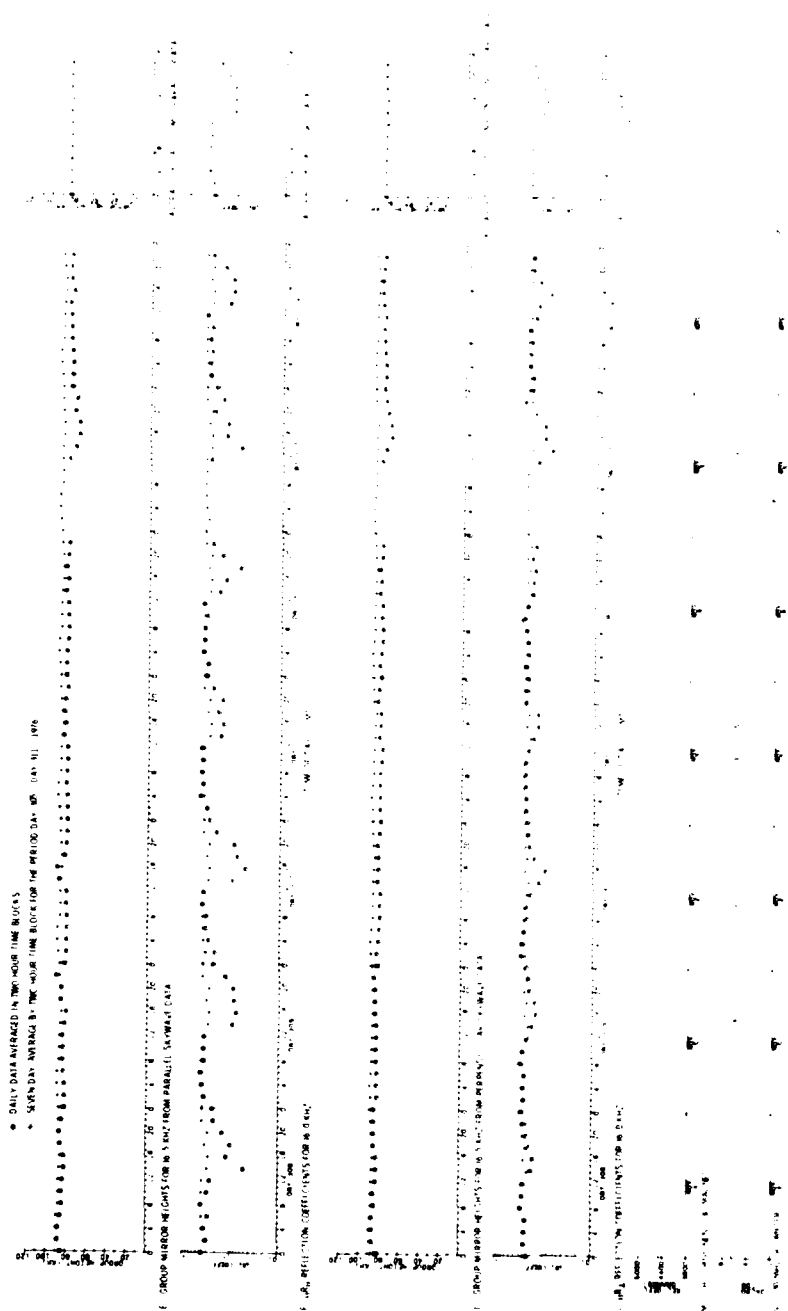


Figure 12. VLF LF Reflectivity Data for the Polar Ionosphere, DAY 408-444 (NOV-DAY 414 ON NOV 17-18 1976)



Figure 1. (a) Intensity distribution of the polar ionosphere, DAY 308 (4 Nov)–
 1973, 14–16 N, 14°–16° S, 10°–12° E.
 Part 1. Intensity distribution.

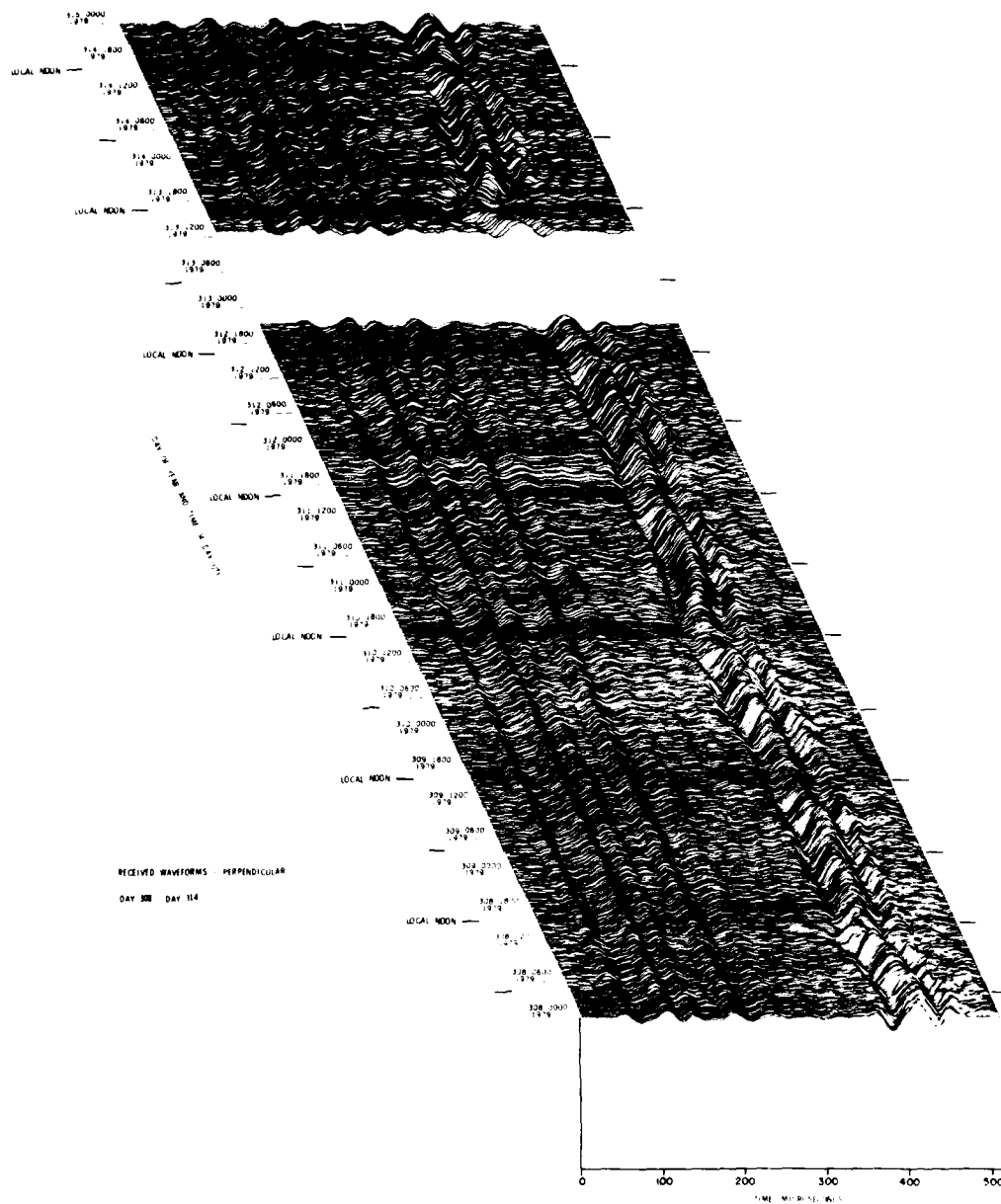


Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 308 (4 Nov)-
DAY 314 (10 Nov) 1979 (Cont.)
Part S. 1 Waveform Display

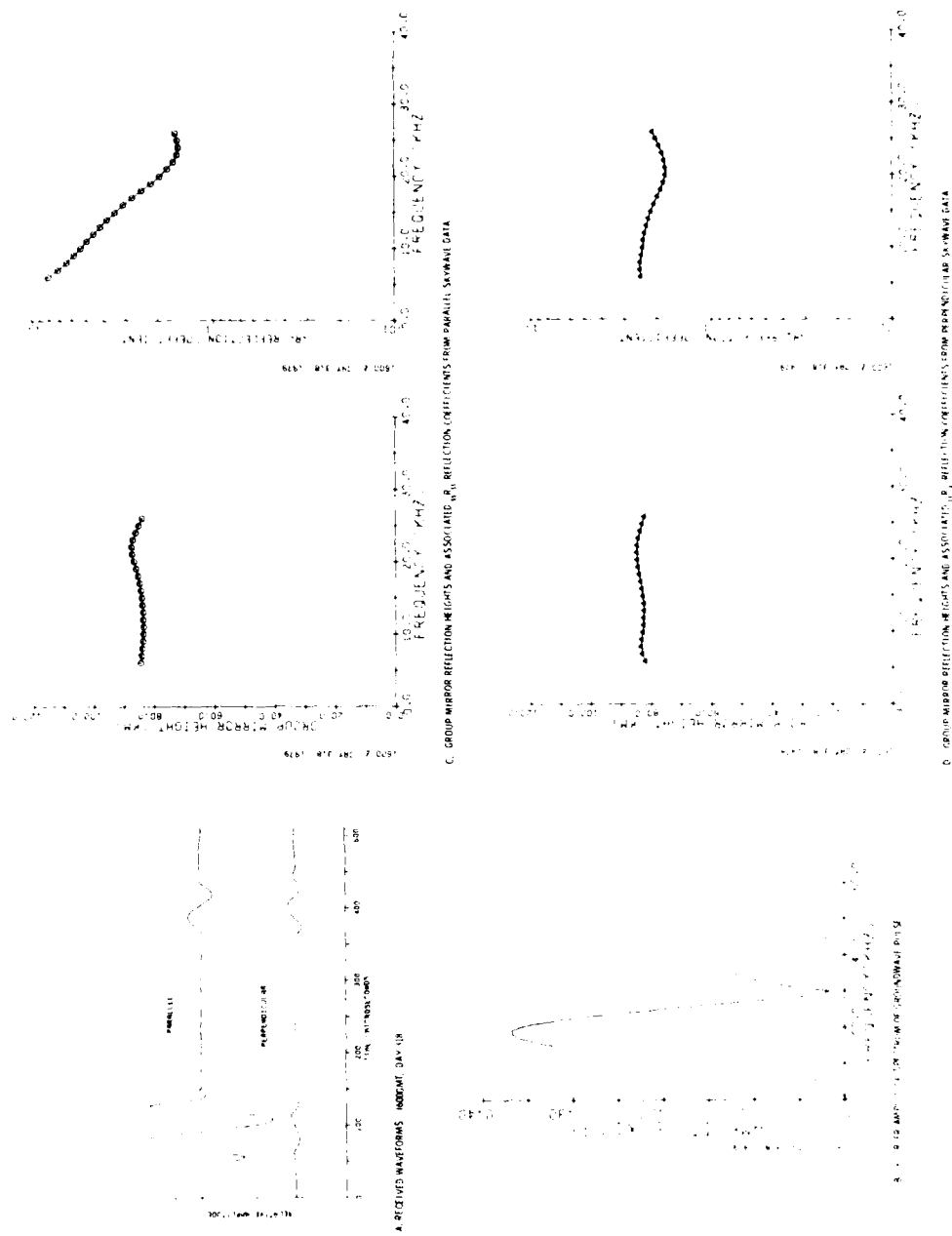


Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 315 (11 Nov)-DAY 321 (17 Nov) 1979

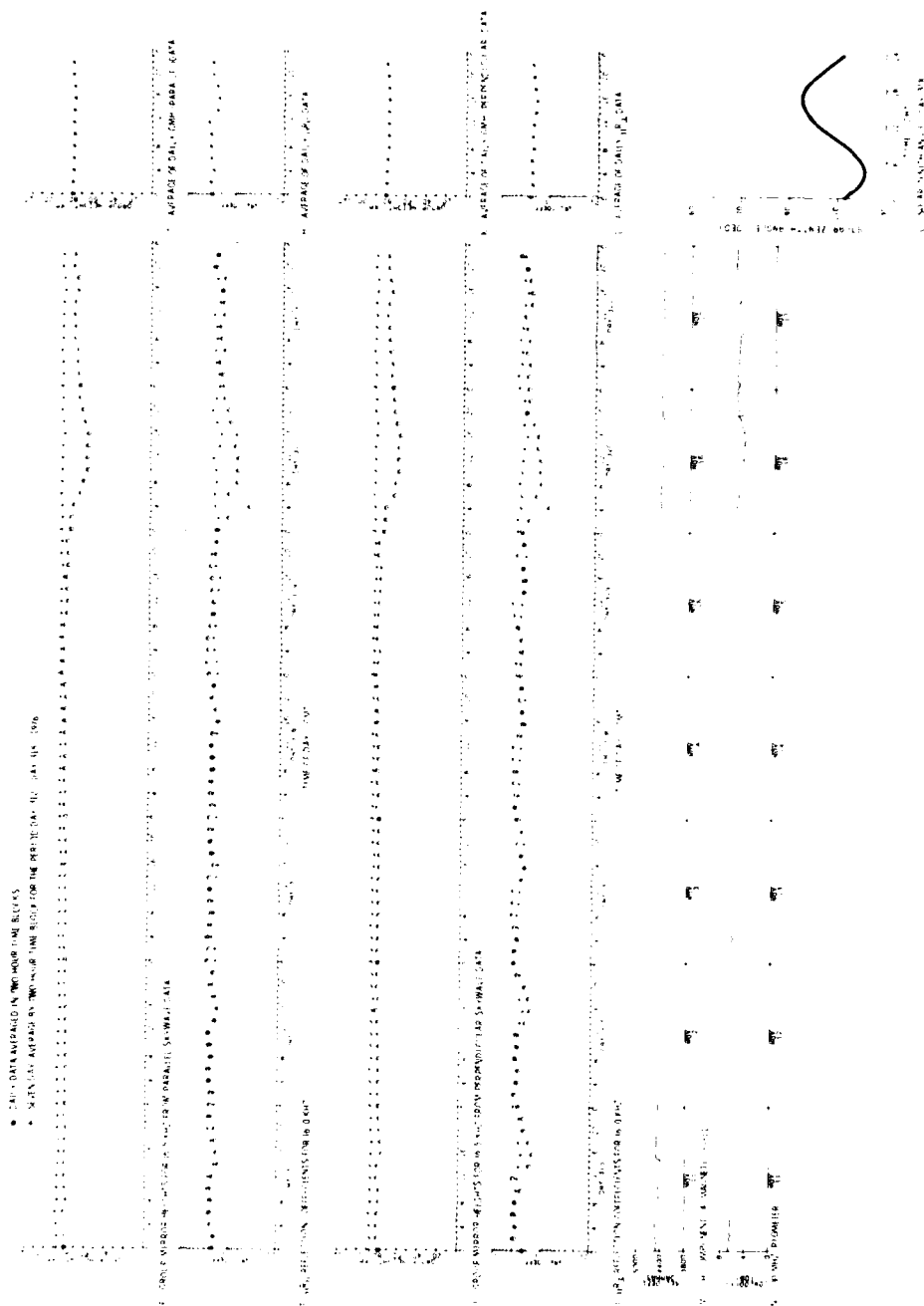


Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 315 (11 Nov)-DAY 321 (17 Nov) 1979 (Cont.)

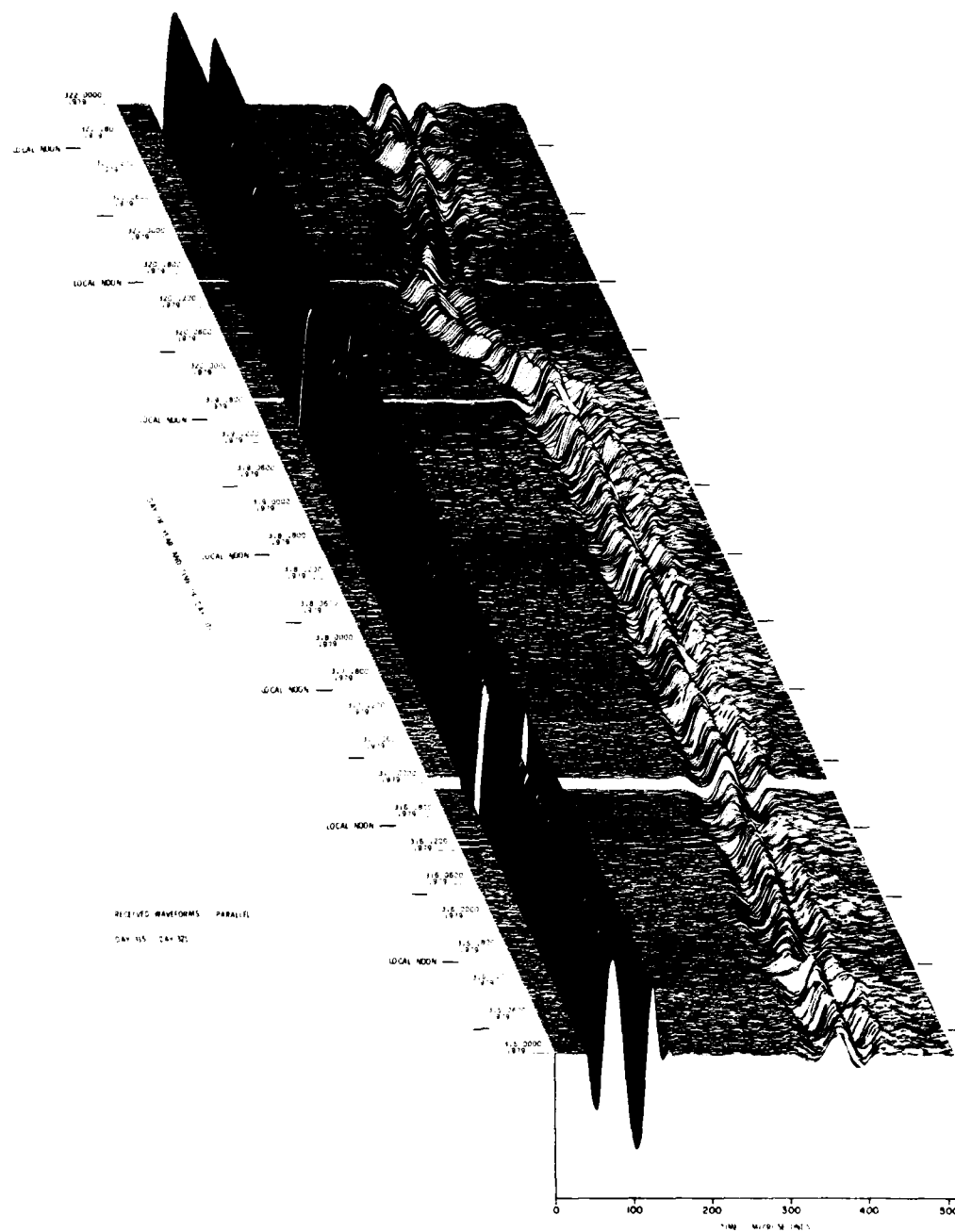


Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 315 (11 Nov)—
DAY 321 (17 Nov) 1979 (Cont.)
Part R. || Waveform Display

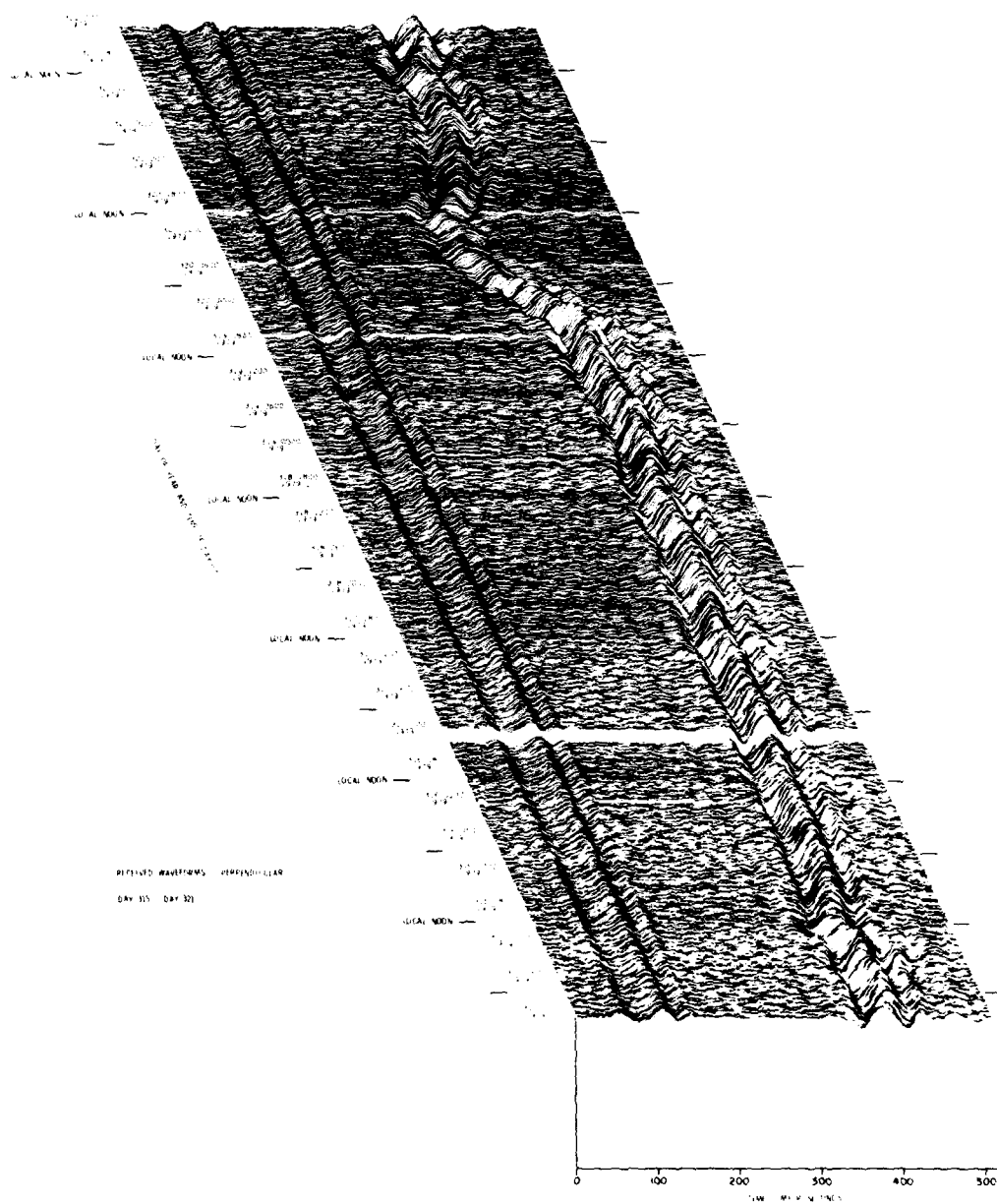


Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 315 (11 Nov)-
DAY 321 (17 Nov) 1979 (Cont.)
Part S. 1 Waveform Display

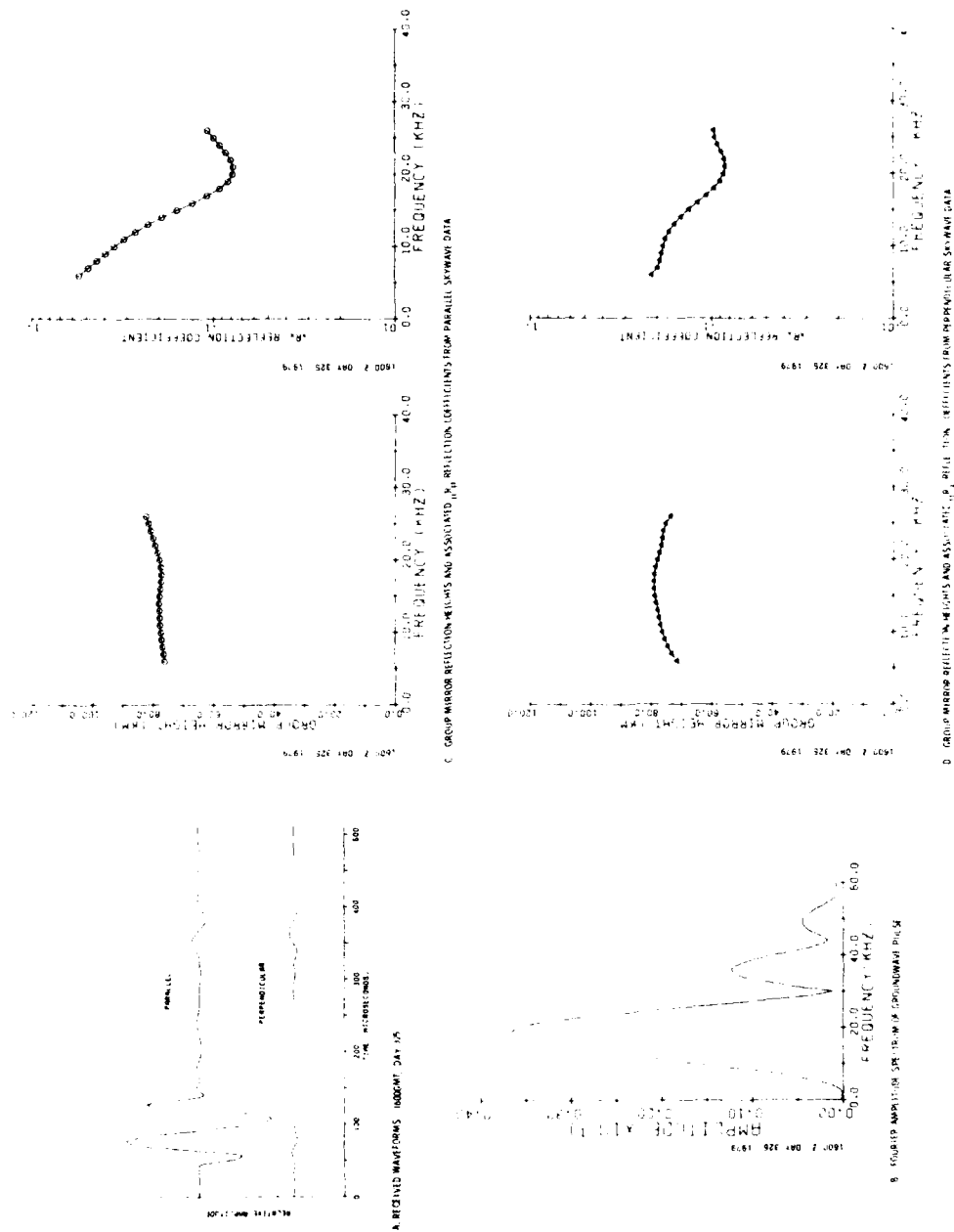


Figure 14. VLF/IF Reflectivity Data for the Polar Ionosphere, DAY 322 (18 Nov)-DAY 328 (24 Nov) 1979

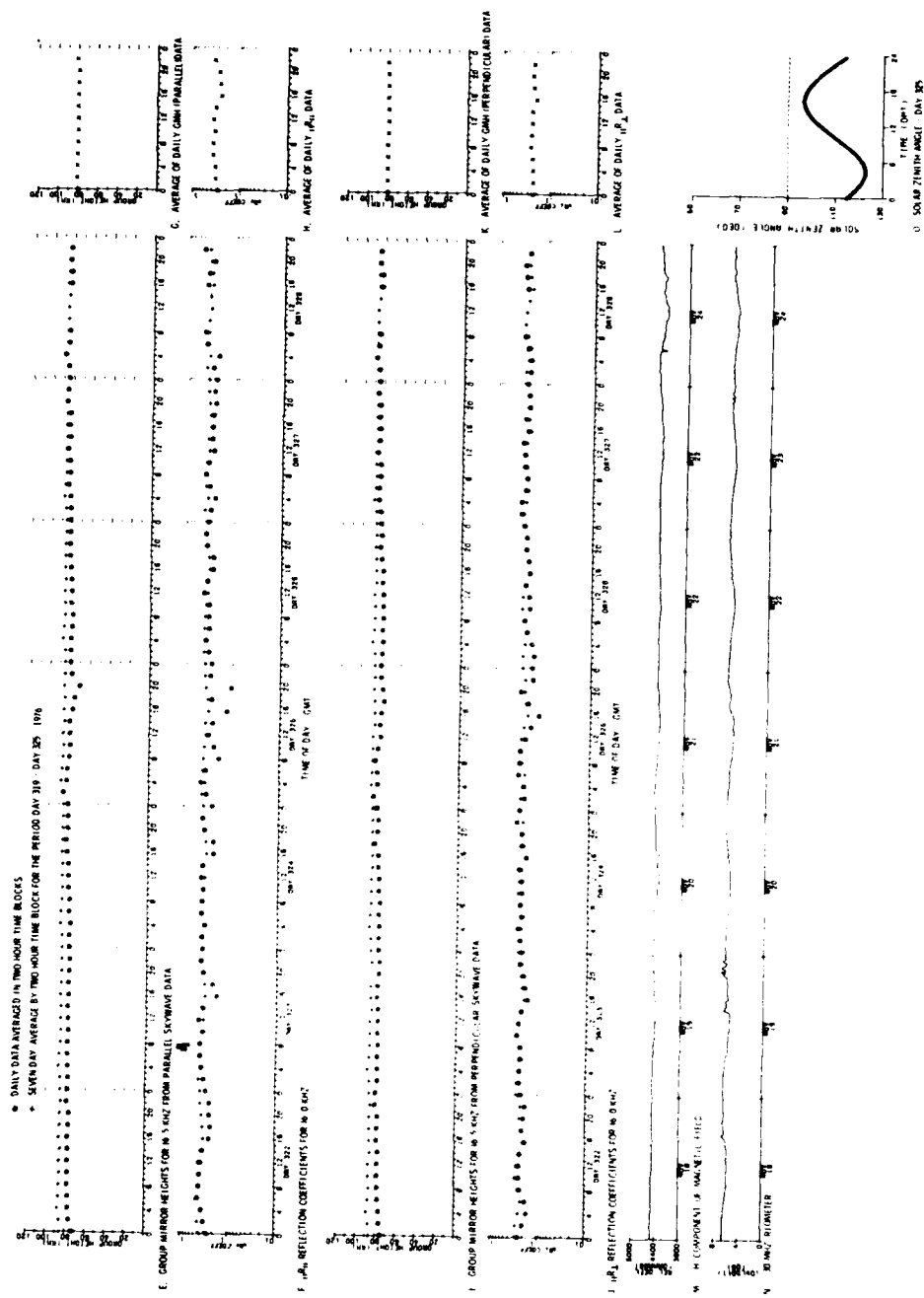


Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 322 (18 Nov)–DAY 328 (24 Nov) 1979 (Cont.)

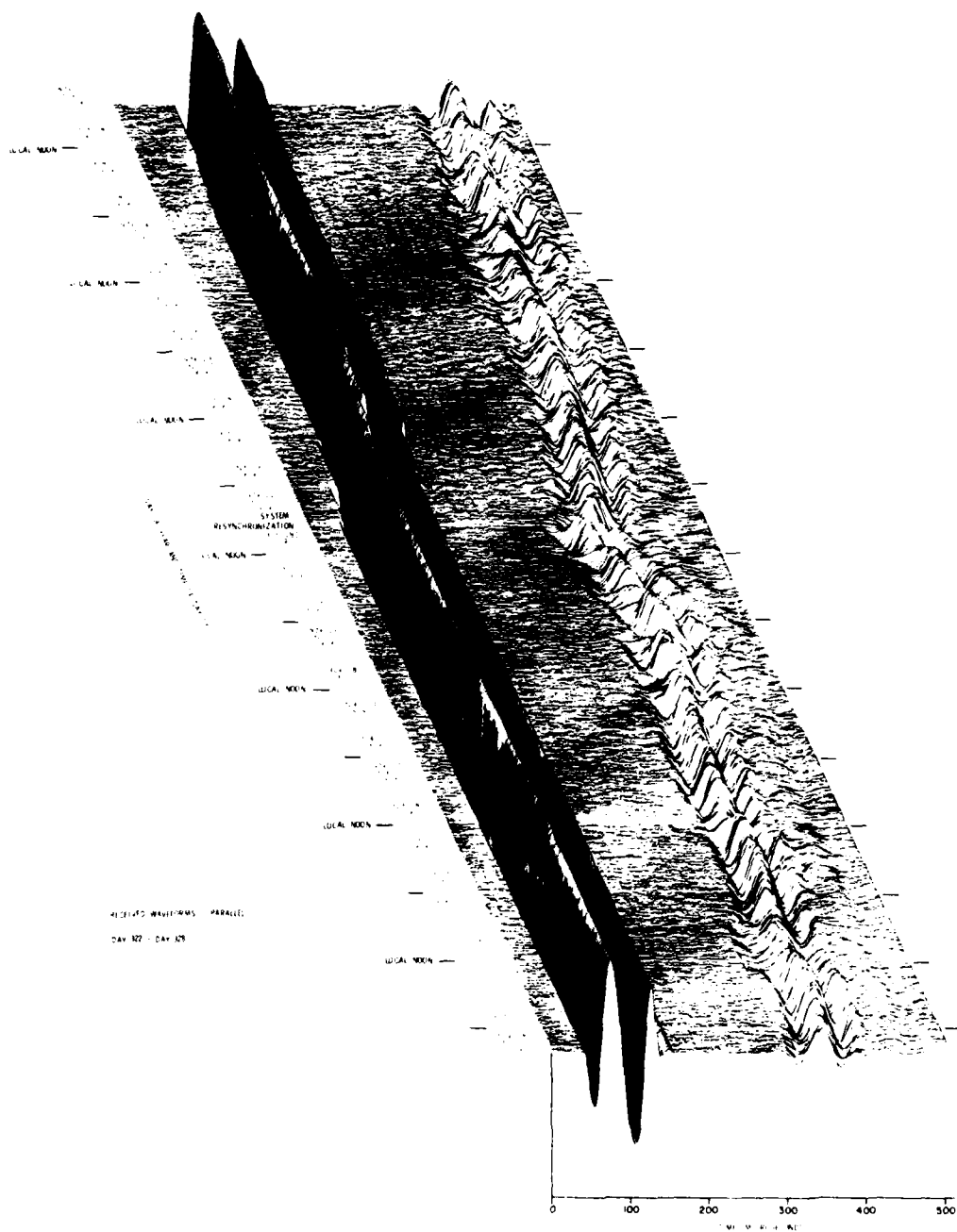


Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 322 (18 Nov)-
DAY 328 (24 Nov) 1979 (Cont.)
Part R. || Waveform Display

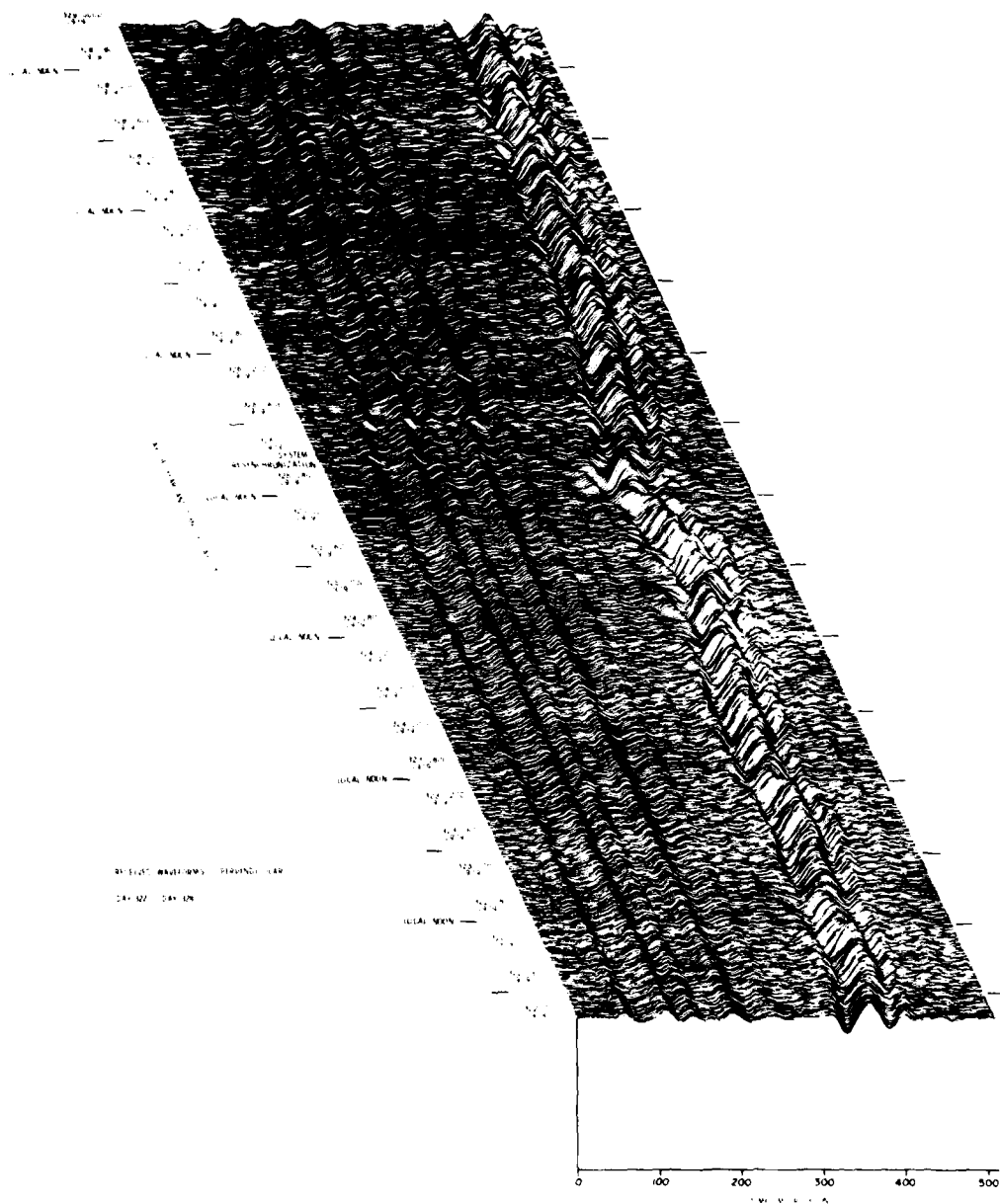


Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 322 (18 Nov)—
DAY 328 (24 Nov) 1979 (Cont.)
Part S. 1 Waveform Display

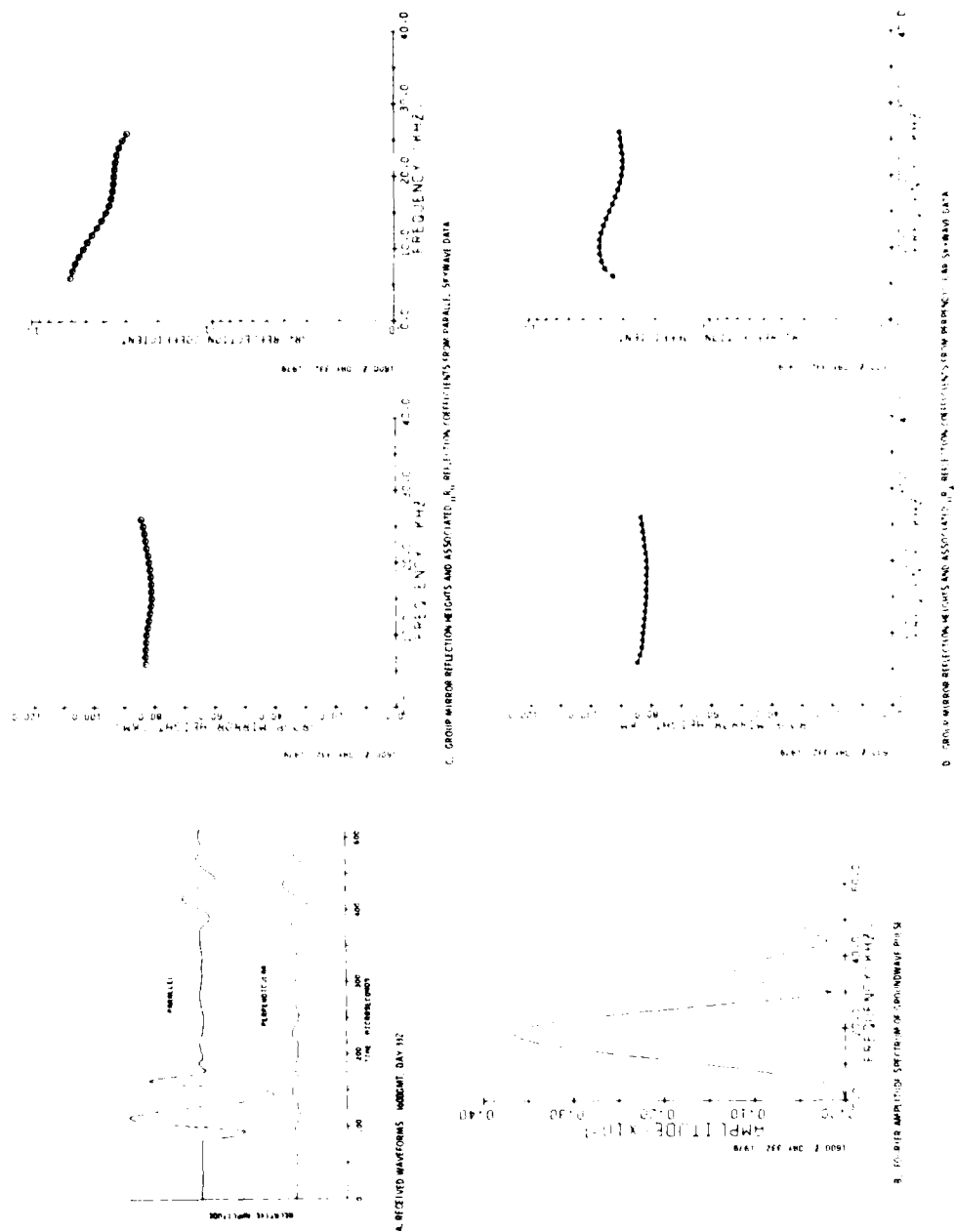


Figure 15. VI.F/LF Reflectivity Data for the Polar Ionosphere, DAY 329 (25 Nov)-DAY 335 (1 Dec) 1979



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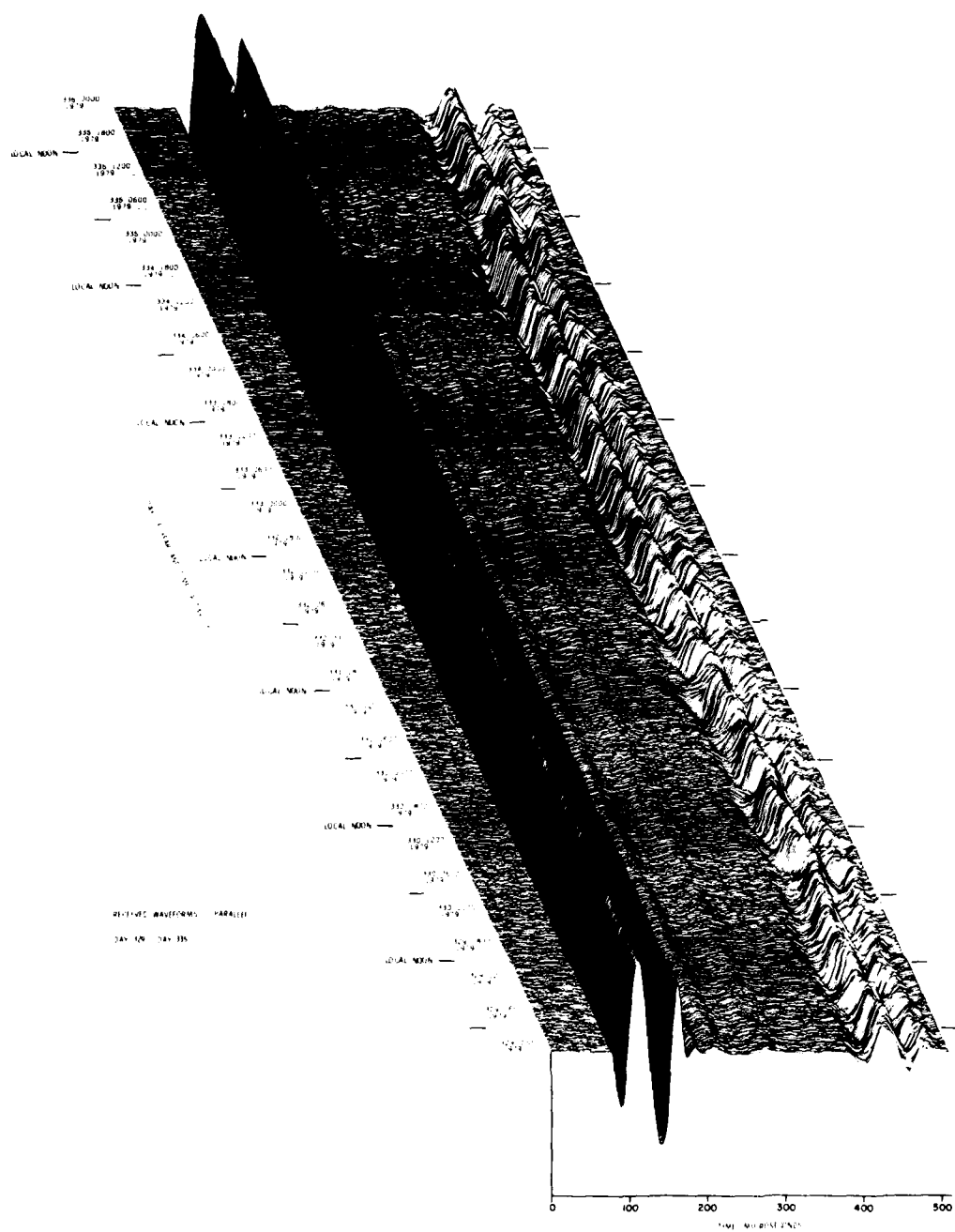


Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 329 (25 Nov)—
DAY 335 (1 Dec) 1979 (Cont.)
Part R. Waveform Display

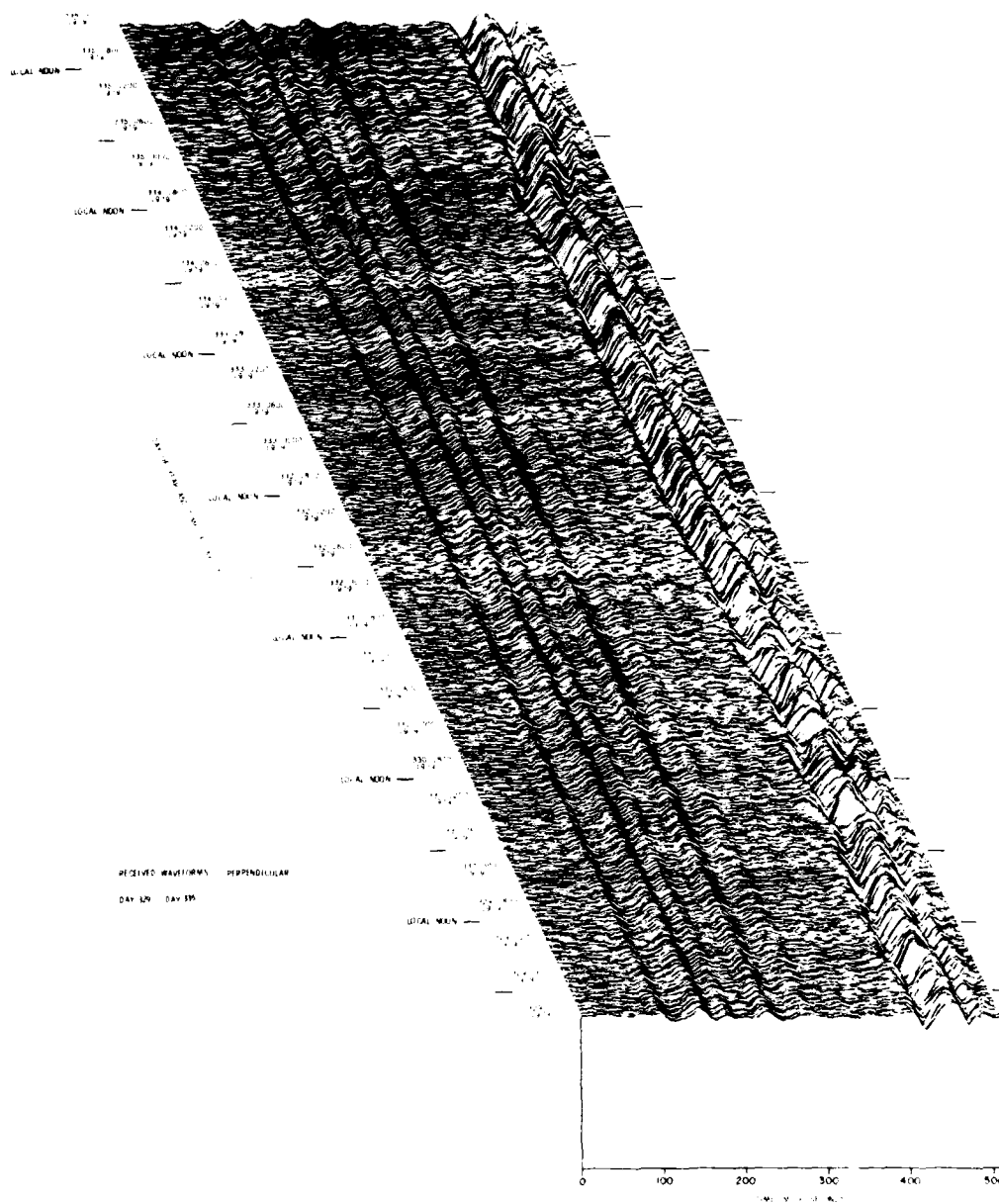


Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 329 (25 Nov)-
DAY 335 (1 Dec) 1979 (Cont.)
Part S. 1 Waveform Display

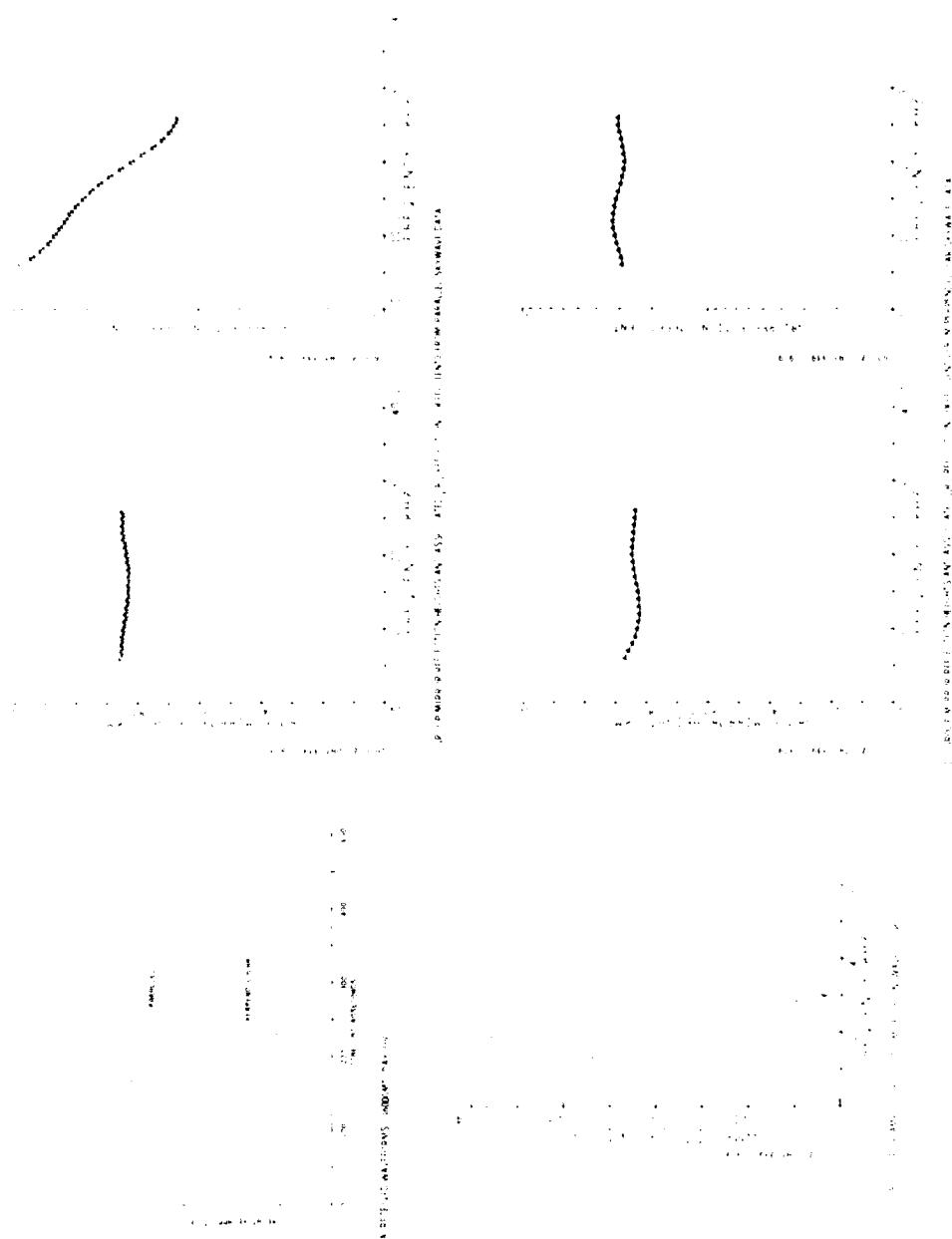


Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 336 (2 Dec)-DAY 342 (8 Dec) 1970

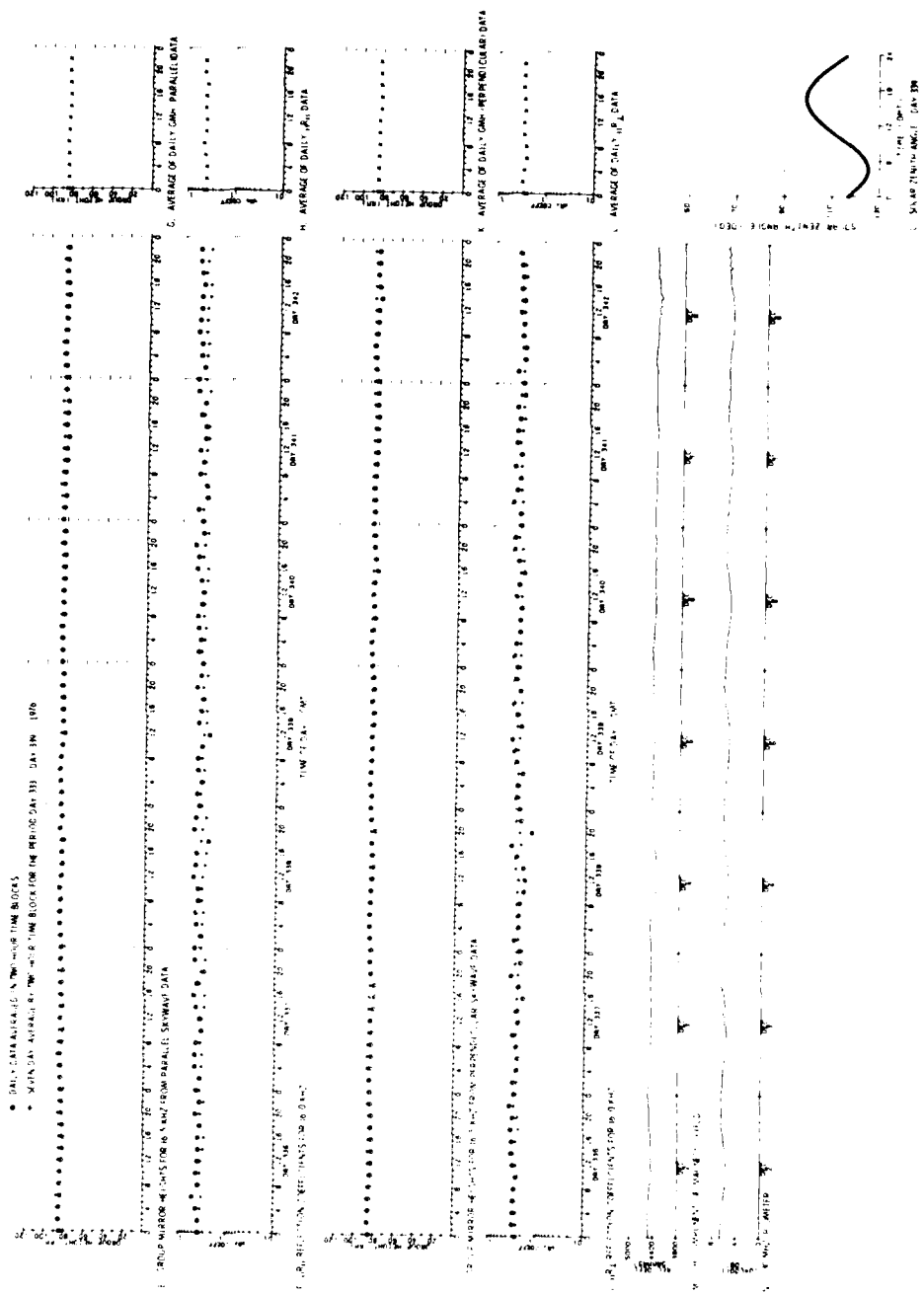


Figure 16. VI.F/I.F Reflectivity Data for the Polar Ionosphere, DAY 336 (2 Dec)-DAY 342 (8 Dec) 1979 (Cont.)

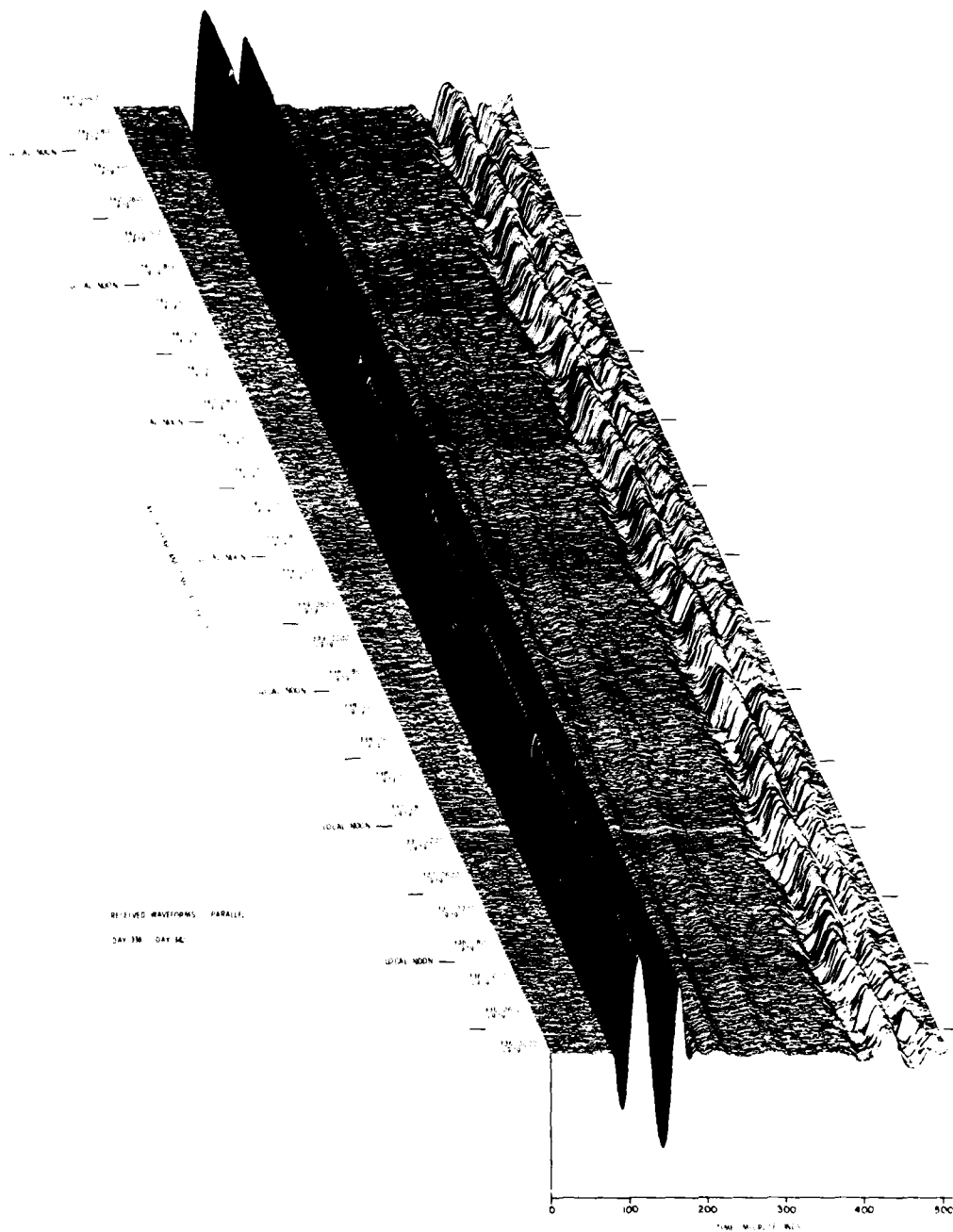


Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 336 (2 Dec)-
 DAY 342 (8 Dec) 1979 (Cont.)
 Part R. || Waveform Display

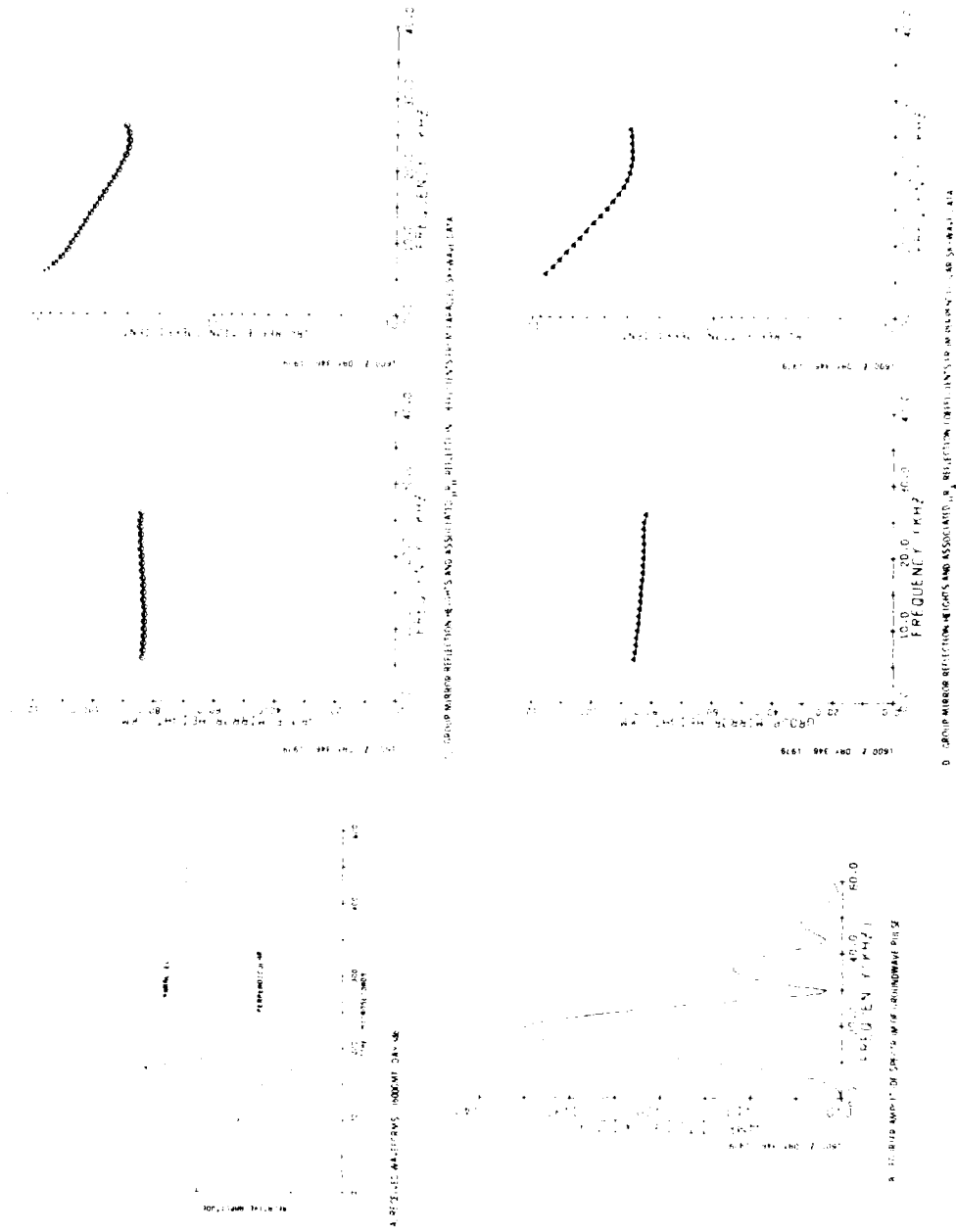


Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 343 (9 Dec)-DAY 349 (15 Dec) 1979

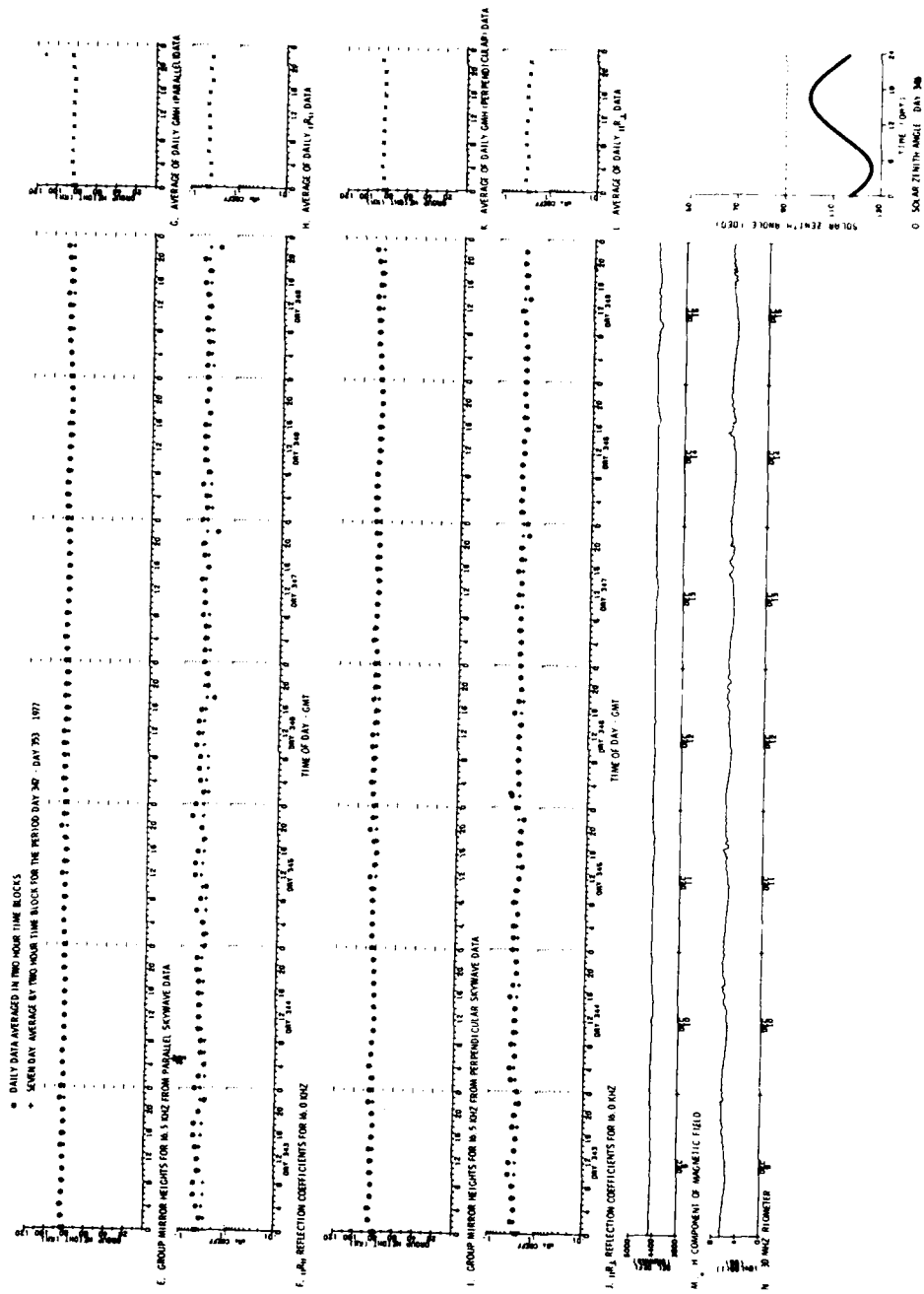


Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 343 (9 Dec)-DAY 349 (15 Dec) 1979 (Cont.)

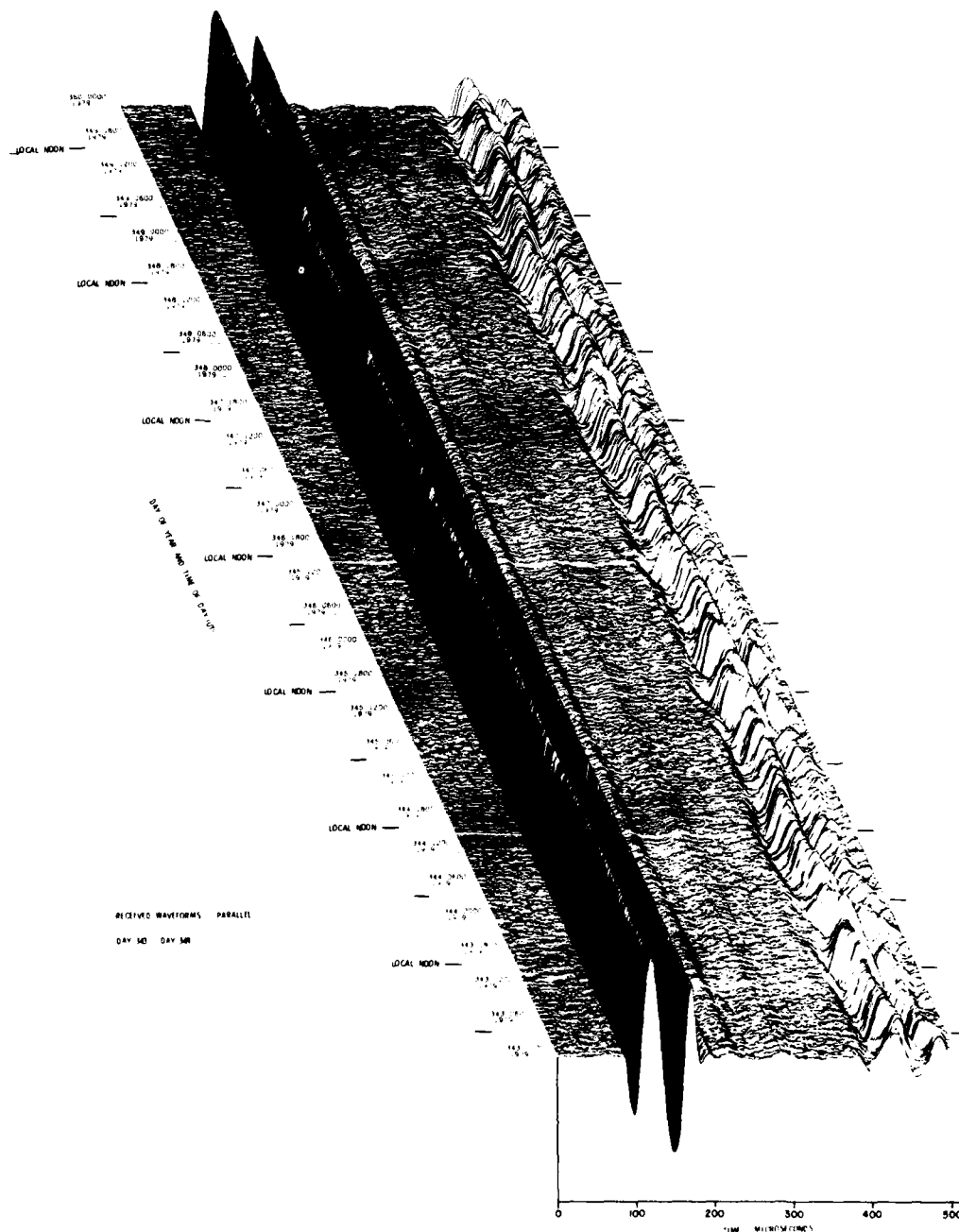


Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 343 (9 Dec)–
DAY 349 (15 Dec) 1979 (Cont.)
Part R. || Waveform Display

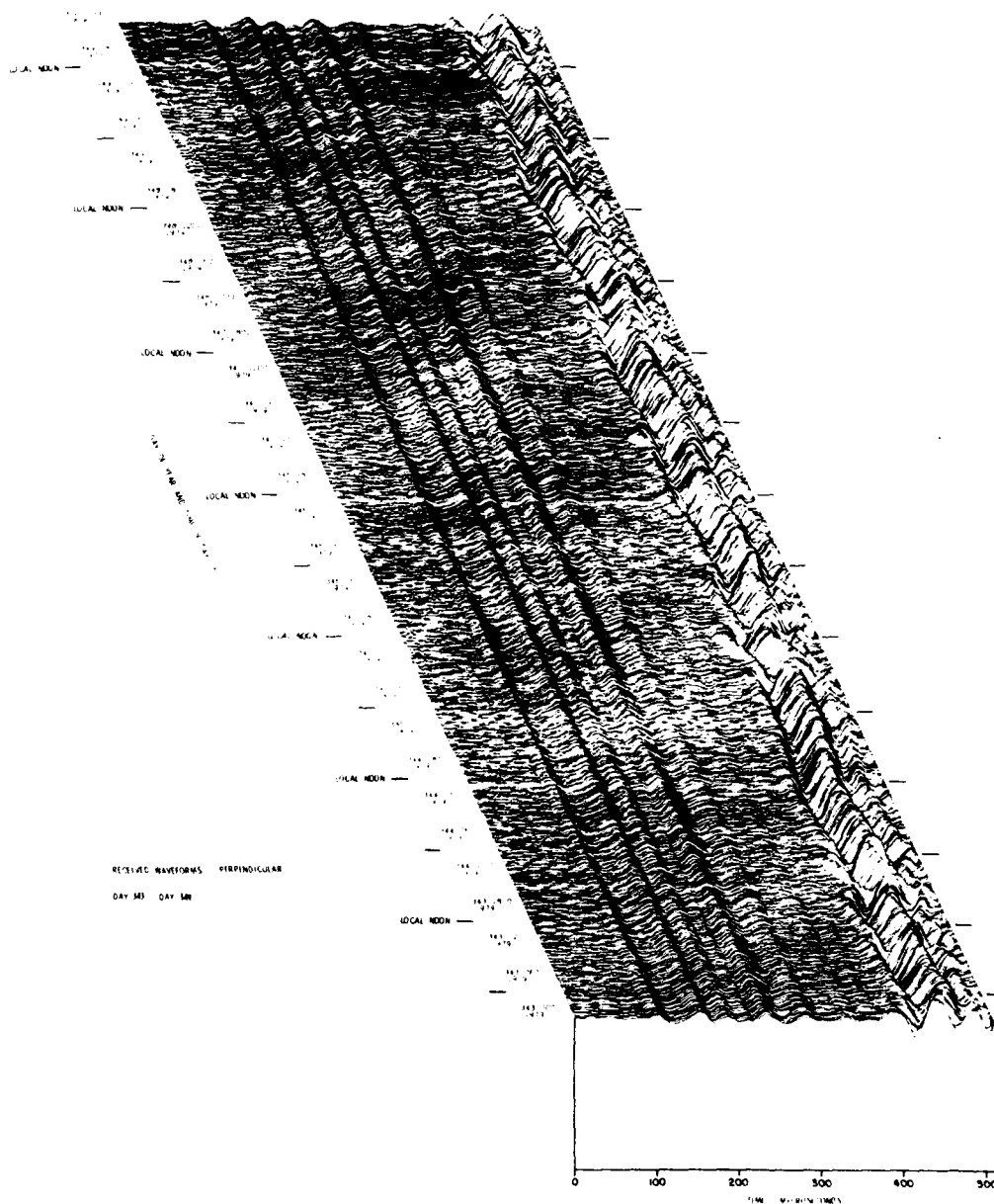


Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 343 (9 Dec)-
DAY 349 (15 Dec) 1979 (Cont.)
Part S. 1 Waveform Display

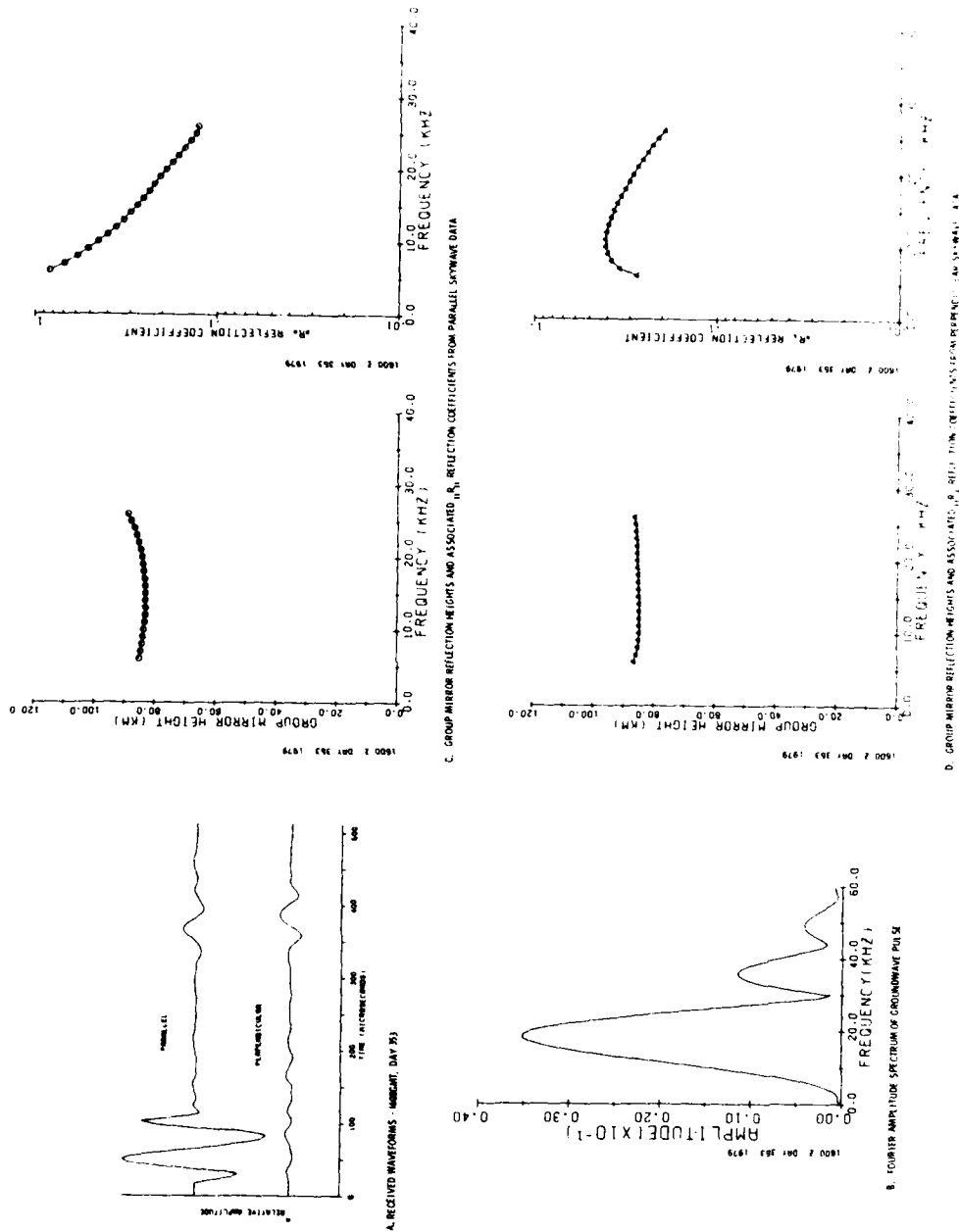


Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 350 (16 Dec)-DAY 356 (22 Dec) 1979

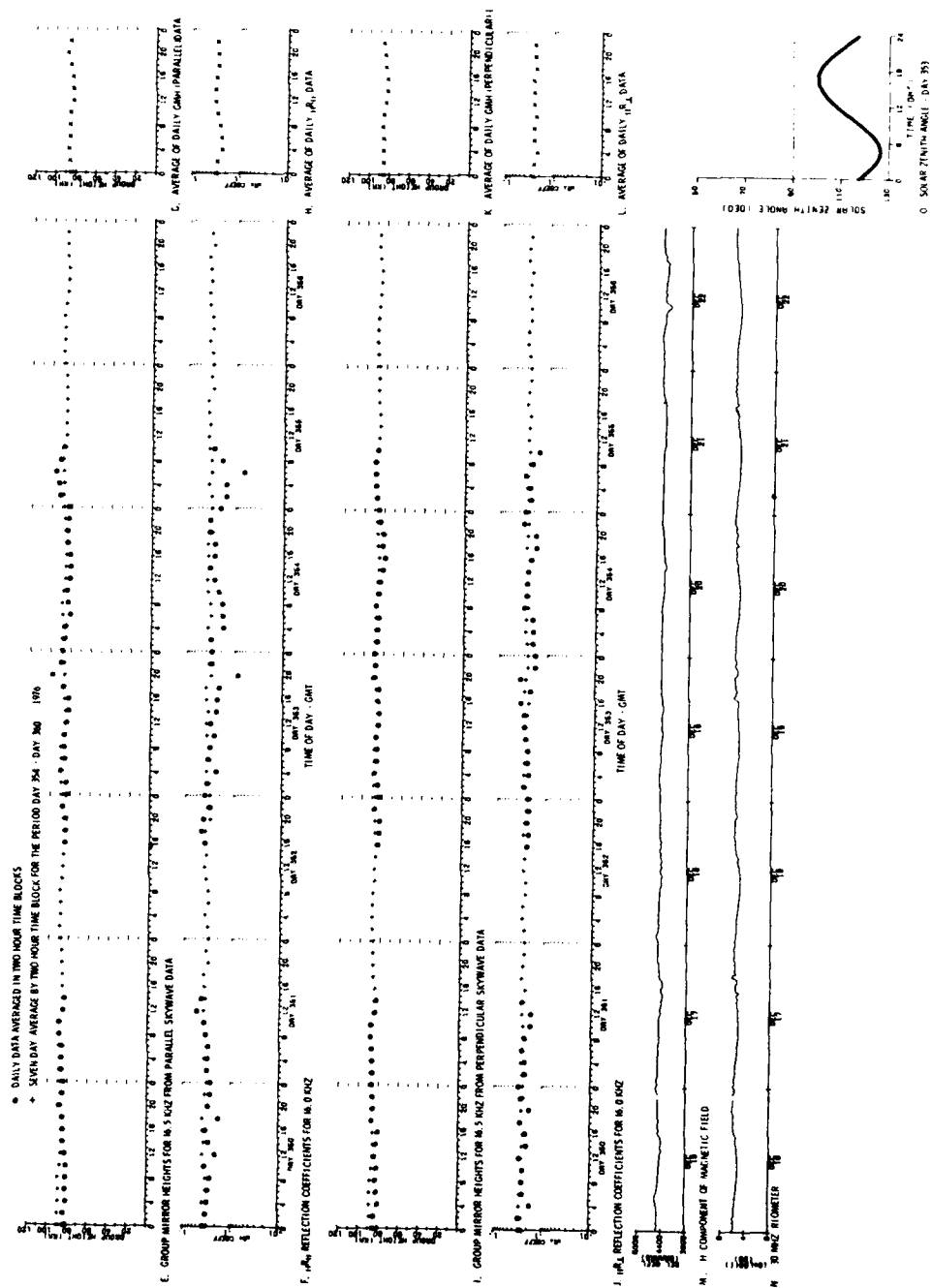
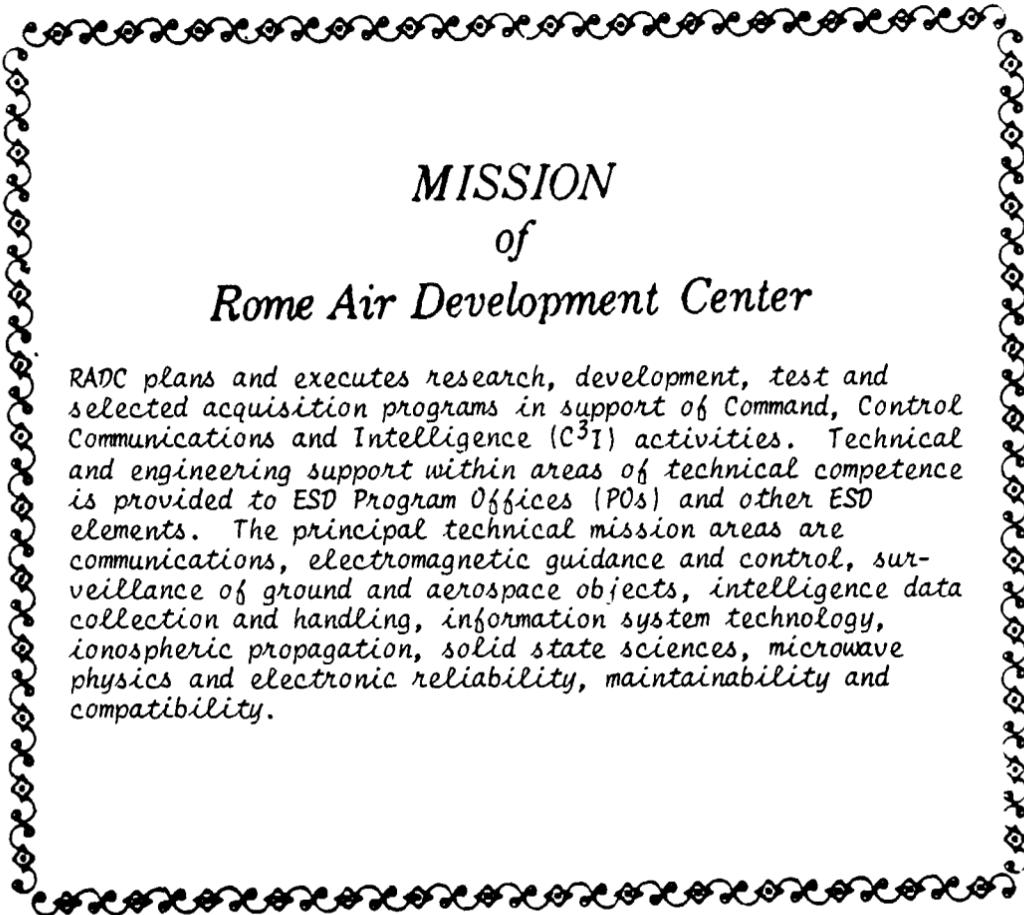


Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 350 (16 Dec)–DAY 356 (22 Dec) 1979 (Cont.)

References

1. Lewis, E.A., Rasmussen, J.E., and Kossey, P.A. (1973) Measurements of ionospheric reflectivity from 6 to 35 kHz, J. Geophys. Res. 78:19.
2. Kossey, P.A., Rasmussen, J.E., and Lewis, E.A. (1974) VLF Pulse ionosounder measurements of the reflection properties of the lower ionosphere, Akademie Verlag, COSPAR, July.
3. Wait, J.R., and Howe, H.H. (1956) Amplitude and Phase Curves for Ground-Wave Propagation in the Band 200 Cycles per Second to 500 Kilocycles, Nat. Bur. Stand. U.S. Circ. No. 574.
4. Budden, K.G. (1961) Radio Waves in the Ionosphere, p. 85, Cambridge University Press, London.
5. Rasmussen, J.E., McLain, R.J., Capt, USAF, and Turtle, J.P. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 19 January-2 March 1975, AFCRL-TR-76-0045, AD A022674.
6. Rasmussen, J.E., McLain, R.J., Capt, USAF, and Turtle, J.P. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 2 March-3 May 1975, RADC-TR-76-146, AD A026465.
7. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P., and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 4 May-5 July 1975, RADC-TR-76-270, AD A034023.
8. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P., and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 20 July-20 September 1975, RADC-TR-76-327, AD 036913.
9. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P., and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 21 September-3 January 1976, RADC-TR-76-378, AD 037794.
10. Rasmussen, J.E., Turtle, J.P., Pagliarulo, R.P., and Klemetti W.I. (1977) VLF/LF Reflectivity of the Polar Ionosphere, 4 January-3 July 1976, RADC-TR-77-68, AD A040920.

11. Rasmussen, J. E., Turtle, J. P., Pagliarulo, R. P., and Klemetti, W. I. (1977) VLF/LF Reflectivity of the Polar Ionosphere, 1 August 1976-1 January 1977, RADC-TR-77-141, AD A044050.
12. Rasmussen, J. E., Turtle, J. P., Pagliarulo, R. P., and Klemetti, W. I. (1977) VLF/LF Reflectivity of the Polar Ionosphere, 2 January-30 April 1977, RADC-TR-77-251, AD A047238.
13. Rasmussen, J. E., Turtle, J. P., Pagliarulo, R. P., and Klemetti, W. I. (1977) VLF/LF Reflectivity of the Polar Ionosphere, 1 May-3 September 1977, RADC-TR-77-428, AD 053236.
14. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., and Klemetti, W. I. (1978) VLF/LF Reflectivity of the Polar Ionosphere, 4 September-31 December 1977, RADC-TR-78-95, AD A060918.
15. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., and Klemetti, W. I. (1978) VLF/LF Reflectivity of the Polar Ionosphere, 1 January-22 April 1978, RADC-TR-78-186, AD A062534.
16. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., Cooley, R. L., TSgt, and Klemetti, W. I. (1979) VLF/LF Reflectivity of the Polar Ionosphere, 23 April-2 September 1978, RADC-TR-79-100, AD A074762.
17. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., Cooley, R. L., TSgt, and Klemetti, W. I. (1979) VLF/LF Reflectivity of the Polar Ionosphere, 3 September-30 December 1978, RADC-TR-79-178, AD A074475.
18. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., Cooley, R. L., TSgt, and Klemetti, W. I. (1979) VLF/LF Reflectivity of the Polar Ionosphere, 31 December 1978-5 May 1979, RADC-TR-79-273, AD A083240.
19. Pagliarulo, R. P., Turtle, J. P., Rasmussen, J. E., Cooley, R. L., TSgt, and Klemetti, W. I. (1980) VLF/LF Reflectivity of the Polar Ionosphere, 6 May-1 September 1979, RADC-TR-80-12, AD



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